# DESIGNING AND CONSTRUCTION OF ROADS, SUBWAYS, AIRFIELDS, BRIDGES AND TRANSPORT TUNNELS

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## FEATURES OF THE STRESS STRAIN OF CERAMSITE POWDER MODIFIED SMA PAVEMENTS

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**Statement of the problem.** The task of improving the performance characteristics of crushed stone-mastic asphalt concrete by modifying them with porous powder materials, using the example of expanded clay powder, is considered.
**Results.** As a result of experimental studies features of the deformative behavior of the proposed compositions were identified at different operating temperatures. The graphs of dependences of the impact of expanded clay powder on the viscosity and relaxation time of the stresses of crushed stone-mastic asphalt concrete were obtained.
**Conclusions.** It was established experimentally that crushed stone-mastic asphalt concrete modified with expanded clay powder has a higher heat resistance, shear resistance and crack resistance than traditional compositions with stabilizing additives. Increasing these properties leads to an increase in the service life of road surfaces.

**Keywords:** stone mastic asphalt concrete, road pavement, expanded clay powder, rheology, viscosity, stress relaxation, Viatop-66.

**Introduction.** Asphalt concrete is an elastic viscous plastic body which is subject to a whole host of factors, e. g., transport loads, heat, cooling, humidity, etc. Calculations for this type of structures commonly rely on the strength of asphalt concrete and its transport load resistance. Possible shear deformations in hot season or temperature-induced cracks in winter season are not necessarily given any consideration. The reason why these should be is that along with traffic load, these temperature deformations are one of the major factors causing pavement to fail prematurely. In order for temperature effects to be considered in pavement calculations, there has to be a clear understanding of how asphalt concrete functions under transport load both at positive temperatures and under cooling ultimately leading to tensile strains and deformations [9]. These properties of asphalt concrete largely depend on the behavior of the binder under varying conditions. As the temperature of bitumen goes up, shear resistance and strength of asphalt concrete drop due to a reduction of physical and chemical links between mineral particles and a bitumen binder [3, 12].

**1. Viscosity and strain relaxation in asphalt concrete.** In order for asphalt concrete to function properly under varying operational conditions, it is essential that the following conditions are met: sufficient deformation resistance at high summer temperatures (i. e., thermal resistance) and sufficient deformation capacity at low temperatures (i. e., a high crack resistance). Unless these are met, road pavement failures are rather common to occur. Most asphalt concrete pavements in this country these days do not meet the above requirements. The problem can be dealt with by increasing crack resistance of pavements due to a larger internal friction coefficient tgφ and cohesion of mineral grains and that generated by bitumen links. An increase in crack resistance of pavements can be due to use of fillers with a developed rough surface to increase internal friction and cohesion between stone material particles [1—2, 4—8].

Cohesion generated by bitumen links has a direct effect on the likelihood of plastic deformations at high operational temperatures. Larger bitumen activity and viscosity can be achieved by introducing various modifying additives [16—20]. However, if bitumen should be maximum viscous at high temperatures, it should be minimum at negative temperatures as it is under these particular conditions that significant stretching strains occur in asphalt concrete pavements causing cracks, a lower freeze resistance and, therefore, failure of a material. It is necessary that bitumen was maximum viscous at high temperatures and also had a high plasticity at low temperatures. In practice, this seems rather challenging. Therefore in order for these conditions to be met and compositions with most optimal properties to be obtained, the appropriate materials are to be employed. One of them are porous mineral fillers modifying and structuring bitumen in the process of their interaction [10—11, 13—15].

For high-quality evaluation of operating properties and durability of materials, the stress-strain behavior of asphalt concrete should be considered at varying operational temperatures, which is best described in rheology, i. e. the flow behavior study.

One of the most important properties of asphalt concrete as an elastic-viscous-plastic material is strain relaxation. Strain relaxation is uncontrolled decrease (dispersion) of strains in time which is caused by an internal flow of a deformed body (under stable deformation). As the temperature rises, viscosity drops accompanied by rising strain relaxation time for asphalt concrete. Thus relaxation time for asphalt concrete largely depends on the viscosity and temperature.

Viscous or elastic properties in asphalt concrete depend on the load impact and strain relaxation time ratio. If load impact time is very short compared relaxation time, a material functions as an ideally plastic one. If it is long compared to relaxation time, a material displays the properties of a viscous liquid [3, 9, 12].

At negative temperatures asphalt concrete becomes maximum viscous. Under these conditions relaxation time is more than common load impact times. In this case asphalt concrete acts as an elastic material, which results in an increase in its fragility and tensile strength limit $R_p$, which makes crack more likely to occur. If emerging strains are completely or significantly relaxed by the end of a period of a sharp temperature drop, cracks are least likely to appear. Therefore in the winter season it is recommended that relaxation time and viscosity of asphalt concrete is reduced.

At high temperatures viscosity of asphalt concrete is at its lowest, which effectively causes a reduction in strain relaxation times which is comparable or significantly smaller than load impact times, which leads to irreversible plastic deformations. Thus it is necessary that relaxation time and viscosity of asphalt concrete is at its highest.

In this study the effect of a high-dispersion ceramsite powder on such rheological parameters of SMA asphalt concrete mixes as viscosity and strain relaxation times. The compositions of SMA asphalt concrete were modified with the ceramsite powder that was used instead of a stabilizing additive. In order to identify the efficiency of the suggested materials, the standard SMA asphalt concrete was compared with *Viatop* stabilizing additives.

**2. Study of rheological properties of SMA.** Rheological properties of the investigated SMA were researched according to the method in [9]. Rheological parameters were determined for SMA-10 and SMA-15 by testing the sample cylinders with the diameter and height (71.5±1.5) mm at different temperatures. In order to calculate rheological characteristics, geometric parameters (diameter and height) were measured before and after testing and tensile strength limits were also fixed. The rate of the press plate motion during the test was assumed to be $\nu$ = 0.005 cm/sec. Dependencies of the rheological characteristics were investigated at operating temperatures ranging from –10 to +60 °C. The temperature of +60 °C was chosen as, according to natural observations, in the southern parts of the country the pavement temperature could reach this value and during the hot season it can hold for a few hours a day and –10 °C is the temperature at which asphalt concrete functions almost as an elastic body. All of the applied temperatures modeled the operation of asphalt concrete for different states of a material: elastic, elastic-viscous, viscous-plastic and plastic stages.

Rheological parameters were calculated based on the following formulas:

— viscosity coefficient:

$$\eta_м = 400R\frac{h_1^2 \Delta h}{\Delta d^2},$$

where $R$ is the tensile strength limit, MPa; $h_1$ is the height of the sample before the test, cm; $\Delta h$ is a difference between the heights of the sample before and after the test ($\Delta h = h_1 - h_2$), cm; $\Delta h$ is a difference between the diameters before and after the test ($\Delta d = d_1 - d_2$), cm;

— relaxation time:

$$\theta = 400\frac{h_1 h^2}{\Delta d^2}.$$

Rheological parameters were identified for SMA-10 and SMA-15 modified with ceramsite powder. For comparison standard SMA with a *Viatop*-66 stabilizing additive were tested. The dependencies of changes in the viscosity coefficient $\eta_м$ on the temperature $T$ are presented in Fig. 1 and 2 for SMA-10 and SMA-15 respectively.

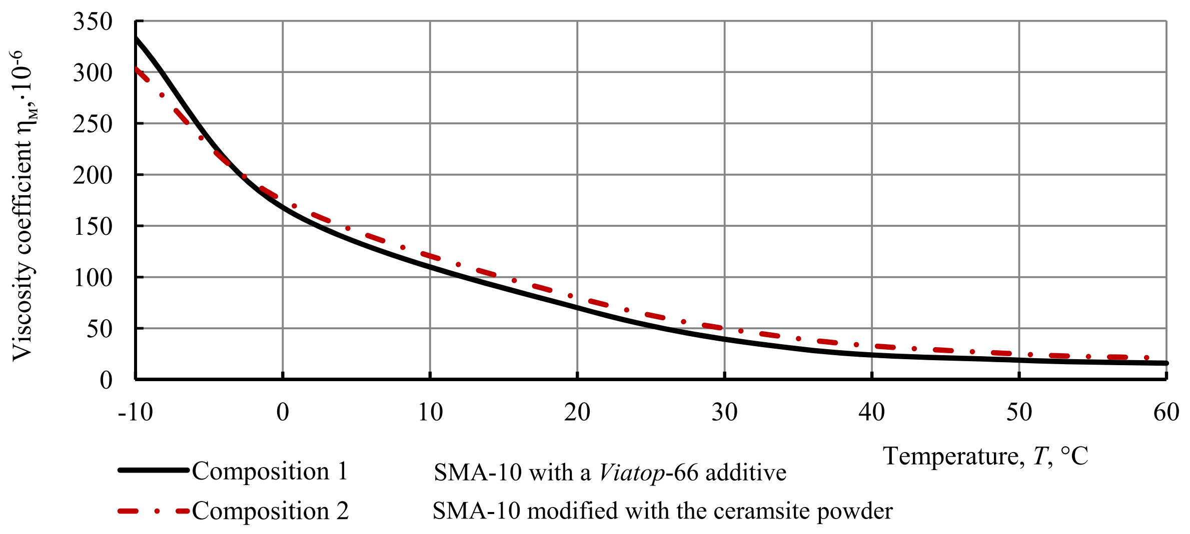


**Fig. 1**. Dependencies of changes in the viscosity coefficient $\eta_м$ on the temperature $T$ for SMA-10

The dependencies of changes in the relaxation time $\theta$ on the temperature $T$ are presented in Fig. 3 and 4 for SMA-10 and SMA-15 respectively.

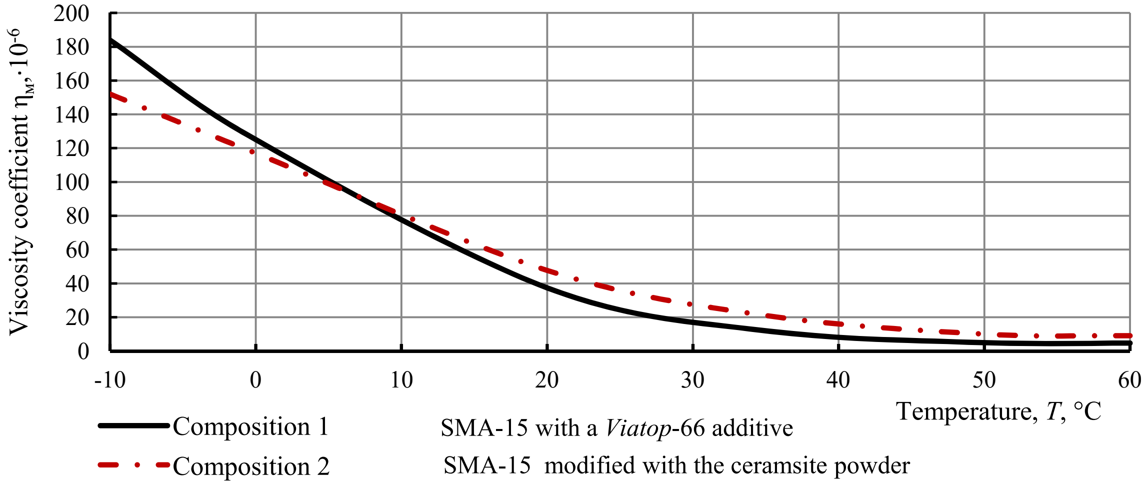


**Fig. 2.** Dependencies of changes in the viscosity coefficient $\eta_м$ on the temperature *T* for SMA-15

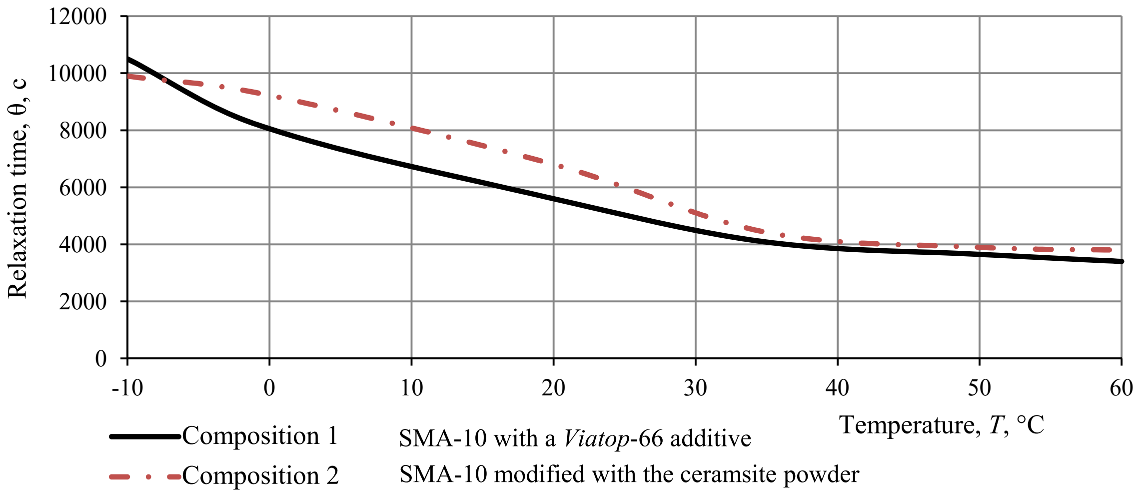


**Fig. 3.** Dependencies of changes in the relaxation time $\theta$ on the temperature *T* for SMA-10

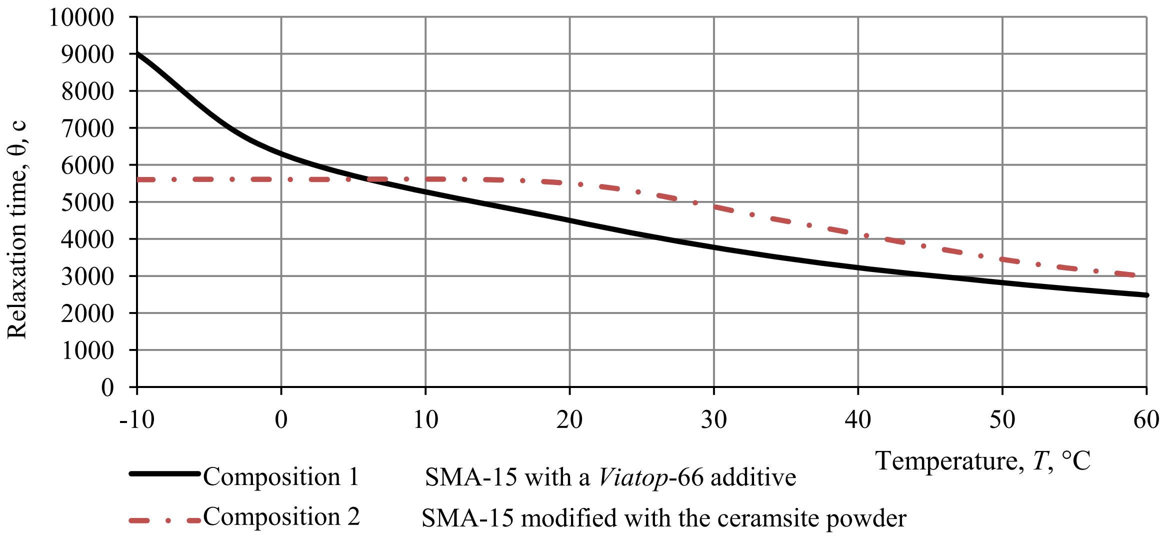


**Fig. 4.** Dependencies of changes in the relaxation time $\theta$ on the temperature *T* for SMA-15

According to the resulting dependencies (Fig. 1—4), SMA-10 and SMA-15 modified with the ceramsite powder have a lower viscosity and a shorter strain relaxation time at low temperatures than the compositions with a *Viatop*-66 stabilizing additive. Thus the modified compositions have a larger deformability and are less fragile and thus more crack-resistant.

It was found that at high operating temperatures the viscosity of SMA-10 and SMA-15 modified with the ceramsite powder is higher than that of the standard SMA-10 and SMA-15 compositions (Fig. 1, 2). As the viscosity of asphalt concrete increases, so does its heat and shear resistance.

According to the dependencies (Fig. 3, 4), strain relaxation time of modified SMA is longer than for the standard compositions making plastic deformations less likely at high operating temperatures.

**Conclusions.** Through the course of the studies of rheological characteristics of SMA asphalt concrete the following conclusions were made:

— at negative operating temperatures SMA modified with ceramsite powder are highly crack-resistant and less fragile than standard SMA with a *Viatop*-66 stabilizing additive;

— at high operating temperatures they have a high shear and heat resistance as well as plastic deformation resistance.

We argue that an increase in the rheological and operational properties of modified SMA is due to SMA asphalt concrete ceramsite powder mixes.

Besides, porous powder materials (e. g., high-dispersion sieves of ceramsite crushing) included into asphalt concrete and bitumen and mineral compositions allow the heat conductivity of materials and thus temperature strains in pavements to be reduced, which causes a significant freeze and crack resistance of materials.

According to the study, due to the topography and microstructure of a surface as well as interaction with a bitumen filler, use of porous powder materials contributes to improving operational and rheological characteristics of SMA and thus longer life cycles of pavements.

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