Utilization of man-triggered wastes by using them in road construction

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Abstract. The possibility of using bituminous-salt masses (BSM), obtained from the destruction of chemical weapons of the organophosphorus group, is considered in the article as an additive improving the mechanical and physical characteristics of the asphalt and bitumen emulsions. When neutralizing poisonous substances with monoethanolamine, salts of methylphosphonic acid (reaction mass) are obtained which exhibit the effect of surface-active substances. Laboratory tests established that the introduction of BSM into the composition of the bitumen concrete leads to almost two-fold increase in the compressive strength and splitting during the compression. The use of the galvanic slurry of alkaline etching as a mineral powder for the bitumen concrete leads to an improvement in mechanical properties so as the alkaline medium leads to a decrease in the surface tension of oil bitumen which causes an increase in the degree of application property and the formation of a more dense dispersed structure of the bitumen concrete. It helps to greatly increase the technological and operational parameters of a road surface. As BSM is a waste its application will improve the economic parameters of BE and bitumen concrete.

1. Introduction
The development of any civilization is associated with the formation of a large amount of various type waste. A of the utilization of these wastes appears at the same time problem. The rate of waste generation largely outstrips the degree of organization and the possibility of their disposal, which causes their considerable accumulation. Wastes from high-industrial production have a higher degree of complexity in their disposal. This type of waste can be attributed galvanic slurry (GS) pipe plant (Kamensk-Uralsky, Sverdlovsk region., Russia) and waste from the destruction of chemical weapons of the organophosphorus group the so-called bitumen-salt mass (BSM).

2. Urgency
These wastes are concentrated in very limited areas and therefore there is an urgent need to dispose of them in order to avoid the cumulative effect of environmental impact and exclusion of negative environmental impacts.

3. Problem statement
To achieve the maximum efficiency in the disposal of these wastes, their chemical and mineralogical composition was studied as well as the scope of their possible application. It has been established that GS contain various oxides in a finely dispersed state with alkali metal oxides predominating and
according to the 4th danger class [1]. That is why in determining the scope of use the direction of the application was considered with the minimal preliminary preparation in the road construction as a mineral powder as one of the important components of bituminous binder bitumen concrete [2,3].

Russia signed the convention about the non-proliferation and destruction of chemical weapons and practically has completed its destruction nowadays [4-6]. The production of BSM is determined by using of a two-stage technology for the destruction of the organophosphorus group of toxic agents (sarin, soman, VX) [7-9]. When considering the composition of BSM it should be noted that about 97 % of it contains oil bitumen and the remaining part is a reaction mass (RM) [10,11]. Neutralization of toxic substances is carried out with monoethanolamine and as a result various salts of methylphosphonic acid are formed. Thus, the considered man-triggered wastes possess a favorable combination of the properties of their application in combination with oil bitumen and therefore are suitable for use in bitumen concrete and bitumen emulsions of road surfaces.

4. Theoretical part

In the theoretical analysis of the influence of the positive qualities of GS on the improvement of physical and mechanical properties it can be assumed that having a large total surface due to the finely dispersed components it is possible to ensure the formation of the required thixotropic parameters [12-14]. It is known that up to 80% of the total surface of mineral components falls on mineral powders in this case with GS. The change in the thixotropic properties of petroleum bitumens occurs when they are adsorbed on the surface of mineral components and the oil bitumen is transferred to the film state [15,16]. Consequently, the larger the total surface that is formed by the mineral powders the more bitumen in the film state the greater the degree of the required thixotropic characteristics.

When introducing into the composition of the bitumen concrete mixture of BSM the properties of the bituminous binder will change which will positively affect the formation of the structure of the bitumen concrete conglomerate. The reaction mass contained in BSM exhibits the properties of surfactants (surfactants) [17-19]. It has a positive effect on the spreading power of the bituminous astringent mineral components since the largest surface area of the mineral components is covered with bituminous binders, the friction between the particles will be smaller, which will make it possible to create a denser package during the compaction. The latter circumstance will make it possible to obtain bitumen concrete of higher strength characteristics [20].

In addition, bitumen emulsion (BE) is an important component in the construction of the road surfaces. Inclusion in its composition of BSM is justified and the effect of surfactants will positively affect the processes of flocculation and coalescence. An important indicator of BE is the stability during the storage and transportation [21], where the main role will be played by surfactants of BSM providing an increase in time to BE segregation.

The tests of bitumen concrete were carried out in accordance with GOST 12801-98 «Materials based on the organic binders for road and airfield construction. Test methods for compression and splitting». During the compression the results obtained are processed to obtain a mathematical model. So the compressive strength index at a temperature of 200 °C is described by the following regression equation (1) where the factors x1-bitumen (including 20 % BSM), x2-sand, x3-sludge, Y-optimization parameter:

\[
Y = 9.23952 \times x_1 + 6.63238 \times x_2 + 5.8681 \times x_3 - 5.58429 \times x_1 \times x_2 + 5.42786 \times x_1 \times x_3 + 28.3714 \times x_2 \times x_3 - 112.905 \times x_1 \times x_2 \times x_3
\]

(1)

When testing for splitting during compression, the strength parameters allowed to obtain the equation (2) of the following type (the same factors, the testing temperature is 20°C):

\[
Y = 1.75 \times x_1 + 1.27714 \times x_2 + 0.932857 \times x_3 - 0.848572 \times x_1 \times x_2 - 0.231428 \times x_1 \times x_3 - 0.945001 \times x_2 \times x_3 + 17.1451 \times x_1 \times x_2 \times x_3
\]

(2)

Practical significance.
The comparison with the control samples where BSM was replaced by the conventional road oil bitumen it was established that the compressive strength and splitting strengths (according to two characteristic compositions of the planning matrix) corresponded to the values, composition No. 1 - 5.4 MPa (with BSM - 11.68 MPa) and 0.97 MPa (with BSM - 1.95 MPa), in composition No. 2 - 4.21 MPa (with BSM - 12.43 MPa) and 0.94 MPa (with BSM - 1.73 MPa) respectively [22].

The BE test was carried out in accordance with GOST R 52128-2003 "Bitumen road emulsions. Technical conditions for the parameters of the resistance to the segregation and application property". It was found that the introduction of BSM into BE composition leads to inhibition of flocculation and activation of the processes of coalescence. This confirms the manifestation of high physical and technological properties of surfactants in BSM [23]. The determination of the application property parameter by quantitative characteristics was carried out using the dip method (the Kolbanovskaya method) [24,25]. The obtained results showed that the presence of BSM in the BE composition can increase the application property of the mineral components of the emulsions to 99.25 %. The latter circumstance greatly improves the technological and operational qualities not only of BE but also of the entire constructive complex of the road surfaces. In addition, the technological characteristics of BE are significantly influenced by the dispersion parameters such as the size of bitumen microdroplets and their distribution (ratio) in size in the «oil-in-water» system. The dispersion characteristics of BE with a modifying additive (BSM) were determined by using a SHIMADZU analyzer SALD-7191. Since BSM has the properties of surfactants (surfactants), it will significantly affect not only the interaction with the mineral components but also the formation of the dispersion spectrum of the bitumen phase of BE. Analysis of the dispersion spectrum is more expedient to consider in the view of the theory of the densest packages of spheres of different diameters. The latter circumstance allows us to substantiate the technological and thixotropic properties of BE. It is known that in the formation of the closest packing the spheres of the maximum diameter occupy 74% of the volume and the remaining voids are occupied by spheres of smaller diameter. In this case, the spheres have the maximum number of contact points (contact number) among themselves. In BE it is necessary to achieve the minimum value of the contact number, since in the places of contact the surfactant is displaced and reduced on the surface of the bitumen phase drop, which leads to activation of the flocculation processes and this has a negative effect on the indexes such as delamination during the storage and transport. Thus, it is more expedient to form the dispersion spectrum of the bituminous phase in such a way that it would differ to the maximum extent from the parameters of the closest packing. Analysis of the dispersion spectra of BE with BSM showed significant deviations in the size parameters of the bituminous phase formed from the requirements of the tightest packing theory. This fact was confirmed by the results of experimental studies, which showed that a considerable dispersion in the number of large and small microdroplets in the aqueous phase leads to an increase in the time for the onset of flocculation processes. So in some formulations the time of preservation of the highly dispersed state of BE was about 500 hours.

5. Summary.
On the basis of the foregoing it can be concluded unambiguously that the introduction into the compositions of the elements of the road surfaces BSM leads to:

- the increasing of the mechanical characteristics of bitumen concretes such as compression and splitting during the compression;
- the improvement of the physical characteristics of BE such as segregation and application property;
- the improvement of the economic indicators reducing the unit of production as BSM is a waste and requires only the transportation costs.

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