Research Journal of Applied Sciences 9 (12): 1171-1175, 2014
ISSN: 1815-932X

The Management of the Process of Interaction in the System "Organic Binder-Mineral Filler"

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Abstract: The present research contains information on control processes of interaction in the system "organic binder-mineral filler" by mechano-chemical hydrophobization of the latter with the purpose of expansion of a raw-material base in the production of road-building composites from man-made materials.

Key words: Interaction, mineral filler, expansion, raw-material, road-building

INTRODUCTION

The creation of new durable construction materials is closely linked to the forces of cohesion and adhesion. If the concept of "cohesion" is due to chemical communication between components of the body of particles (atoms, ions) and intermolecular interaction, "adhesion" is the molecular attraction between two surfaces in contact heterogeneous solid or liquid phases. Adhesion is the cause of gluing two different substances due to physical or chemical action of intermolecular forces. That is why when developing durable composite materials engineers emphasize a great influence on adhesive interaction in the system of various materials (Belov and Lurie, 2007; Fahlman, 2011).

The fundamental difference between the surface adhesion phenomena and wetting is that wetting takes place in the presence of three paired phases. The great practical importance is possessed by the fact that to increase the wetting it is necessary to increase the adhesion work or reduce work cohesion (surface tension) of liquid for example by introduction of surface-active substances (surfactants), temperature change. The fluid which has a lower surface tension or the work cohesion, wets better. Organic liquids are characterized by a low surface tension and so moisten the most surfaces of various natures and water wets only polar substances (Belov and Lurie, 2007).

In the production of the majority of road construction materials there are used organic binder (bitumen) and stone materials. The water in relation to the resulting system is an aggressive environment in which organic-mineral composites stay most of the time and with which engineers of road sector struggle, trying to defend the road surface.

Adhesion is largely determined by the nature of functional groups of molecules in contact substances. For example, close to water values of adhesion have connections with the same functional groups (in two-phase systems, liquid-liquid). This indicates the orientation of molecules in the surface layer at adhesion. On the phase boundary hydrophilic groups are oriented towards water and they almost completely provide the adhesion to the water. The difference between the work of adhesion to the water and work cohesion in contact with her fluids can serve as a measure of polarity and hydrophility of the latter (Artemenko, 2007).

MATERIALS AND METHODS

The influence of various factors on the process of wetting (Summ and Goryunov, 1976). The influence of roughness on the process of wetting. At deriving the law of wetting the surface of a solid body is considered to be perfectly smooth. In fact, the actual surface is rather complicated micro-relief with bumps and hollows of various shape and size. The roughness has influence on contact angles for two reasons. One of them is the thermodynamic. Irregularities increase the real surface in comparison with perfectly smooth one. The ratio of these areas is called the coefficient of roughness. The second reason is kinetic.

The influence of heterogeneity in the process of wetting. Heterogeneous (inhomogeneous) solid surface consists of areas with different surface energy. Heterogeneity is caused by two reasons-the differences in the crystalline structure and chemical composition.

Structural heterogeneity is characteristic for polycrystalline materials. The surface layer contains many small grains (monocrystals), arbitrarily oriented to each other. Therefore, the outer surface is a chaotic mosaic of different crystallographic faces with different values of surface energies "solid body-gas" and "solid body-liquid".

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Wetting is of great importance to the successful implementation of a number of important technological processes.

Usually, the molecules of wetter are diphilic which is typical for any surface-active substances and are adsorbed on the surface of water, focusing with hydrocarbon chains to the air which means that on the surface water there is created a hydrocarbon film. This explains the reduction of surface tension of the solution and increases the wetting ability to appropriate surface tension of organic nonpolar liquids (Kruglyakov *et al*., 2013; Drelich *et al*., 1994).

However, the increase of durability of building materials is primarily due to the protection from intrusion of water in the construction materials.

For this purpose, in particular for road construction materials, there are used organic binding substances-bitumen, tar, putty and other high-molecular hydrocarbons, forming on the surface of the material a thick waterproof film which seals the pores. The above mentioned high-molecular organic compounds quickly degrade in atmospheric conditions due to the low strength of adhesion to mineral substances, the ability to slow evaporation and lack of resistance to abrupt temperature changes, sunlight, oxygen, air, water, aggressive chemical substances and microorganisms (Rybiev, 2003; Pechenyy, 1990; Gorelyshev, 1995).

This leads to the destruction of a building material due to the caused by the temperature drops strong pressure fluctuations of water vapors, air and condensed water, contained in the pores, especially when it is freezing.

However, construction materials can be protected from harmful effects of water with the help of so-called "water-repellent" (hydrophobic coating with surface-active substances. It is important to note that hydrophobicity is a concept that is different from waterproofing and water-resistance and that hydrophobization doesn't make construction material either waterproof or water-resistant. However, hydrophobization usually increases the waterproofing capacity and water resistance of construction materials so that such protection from destructive and harmful effects of water is of immense practical value (Rebinder, 1979).

Surface-active substances (surfactants): Surface-active substances are substances, the adsorption of which from the liquid on the surface of the border with different phases (solid, liquid or gaseous) leads to a significant reduction of surface tension. In the most general and practically important case the adsorbing molecules (ions) of these substances have diphilic structure, i.e., consist of polar groups and a non-polar hydrocarbon radical (diphilic molecules). The surface activity in respect of the non-polar phase (gas, hydrocarbon liquid, non-polar surface of a solid body) is possessed by a hydrocarbon radical which is ejected from the polar environment (Rebinder, 1979).

Classification of surface-active substances was adopted at the III International Congress on surfactants and recommended by the International Organization for Standardization (ISO) in 1960. It is based on the chemical nature of the molecules and includes four main classes of surfactants: anion-active, cation-active, nonionic and amphoteric. Sometimes, there are distinguished also high-molecular (polymer), silicone surfactants but by the chemical nature of the molecules of these substances they may be classified in one of the above classes.

Anion-active surfactants contain in the molecule one or several polar groups and dissociate in water solution with the formation of long-anions which determine their surface activity. The hydrophobic part of the molecule is usually presented by limit or unsaturated aliphatic chains or alkylaromatic radicals.

Cation-active surfactants reduce the surface tension in a lesser extent than anion-active ones but they can interact chemically with the surface of the adsorbent.

Nonionic surfactants do not dissociate into ions in water. Their solubility is due to the presence of hydrophilic essential and hydroxyl groups in the molecules. Due to the break of hydrogen bonds with increasing temperature the solubility of nonionic surfactants decreases, so the point of turbidity for them the high temperature limit of micellization is an important indicator.

RESULTS AND DISCUSSION

Activated mineral powders for organic-mineral composites: The construction industry is one of the most dynamically developing branches of economy of Russia and foreign countries which widely uses the non-metallic building materials and first of all fine-dispersed mineral powders (Bazhenov, 2006; Babaevskii, 1981; Evstigneeva, 2008; Yadykina *et al*., 2012).

One of the ways to improve the performance of asphalt concrete is the use of high-quality mineral powders. In traditional technologies, there are used carbonate mineral powders, obtained by grinding in ball-tube mills and which are scarce in many regions of the country.

To expand the range of raw materials used as fillers for asphalt concrete will be allowed by the use of non-traditional mineral materials including silica for example, the waste of wet magnetic separation. However, the available raw materials often do not meet the regulatory requirements which forces to use various technologies of their modification which could improve the performance of the finished product.

Waste of Wet Magnetic Separation (WMS) of ferruginous quartzite by chemical and mineralogical composition is close to little ore quartzites. The rock-forming mineral is quartz (over 60%), followed by magnetite (to 8%), the hornblende, iron oxides, pyrite. The chemical composition of the WMS waste also is also characterized by a higher content of iron oxides. WMS is finely-dispersed. It cannot be considered as rubble but only as the artificial sand, containing a lot of iron (the module size is much less; up to 25 million tons are stored every year in tailings).

The modification of mineral powders influences the factors of structure formation of asphalt concrete. The significant strengthening of the structure-forming role of the mineral dust in asphalt and hence, the improvement of structural-mechanical properties of the material can be achieved by physical-chemical activation of powder. The greatest effect can be obtained by combining physical-chemical treatment with mechanical effects. Such conditions are created during the processing of a mineral powder in the process of the breaking. To get the best effect, it's necessary to use for modification of the grains surface the substances which allow bringing the molecular properties of the adsorption layer and environment which have to be filled with powder, closer to each other.

According to the State Educational Standard 52129-2003 the activated mineral powder is a material, obtained by grinding of rocks or solid wastes of industrial production with the addition of activating substances, when grinding bituminous minerals including oil shale. As activating substances there is used the rationally chosen mixture of surface-active substances (surfactants) or products containing surfactants with bitumen.

As the activating agent of the substance we can use stearic acid. By the chemical properties stearic acid is a typical representative of aliphatic carboxylic acids. Stearic acid is contained by glycerides of all animal fats and vegetable oils is found in some types of oil. Its presence significantly improves the conditions of wetting of the particles' surface with bitumen and promotes the formation of chemo-adsorption bonds on the phase boundary.

At getting the activated mineral powder the activating mixture must be fed to the mill along with the material to be ground. In the process of grinding the particles of the mineral powder will be covered with a layer of bitumen, the thickness of which will be only tenths or sometimes hundredths of a micron. Therefore, the activated mineral powders should considerably differ in their properties and influence on the quality of asphalt concrete from mineral powders, not treated by activating mixture in the refining process (Cosmin and Ahmed, 2003; Rapoport *et al*., 2010; Trautvain and Yadykina, 2013).

Among the manufacturers of activated mineral powder in Russia there remains basically the Kikerinsky plant in the Leningrad region which from the activator-second fat tar has transferred to the distillation residues of FLC supplied from central regions of the country 1500-2000 km away. The delivery of chemicals suitable for activation of the mineral raw materials, results in a considerable rise in prices of final products.

Manufacturing, the activated mineral powders in the European part is practically not represented. The current practice is using instead of the mineral powder the limestone screenings, characterized by highly-developed pore system. Apart from the filtration of low-molecular components of bitumen there occurs the reduction of the thickness of bitumen films around mineral materials (as a result of the increased surface area). As a result of interaction of bitumen with porous stone materials the selective filtering of bitumen components into the pores takes place. In this regard, the composition of bitumen in the adsorption layers is changed and consequently its properties in the composition of asphalt concrete are changed too. As a result of these processes there increase rigidity and fragility (including under the action of low temperatures) of asphalt in the covering. All this taken together may be considered as one of several reasons of premature cracking, observed on the roads of the Belgorod region (abnormally rapid cracks appearing in the covering in 1-2 years after making the asphalt-concrete layers), lack of corrosion resistance and intensive aging of the asphalt covering.

The above stated proves the necessity of production and mass application of mineral powders in road construction.

The development of road construction can be achieved through a wide use in the production technology of mineral powders, local road-building materials, secondary raw materials, industrial products and industrial wastes. Such, mineral materials often do not meet the requirements of the standards on traditionally used materials and in their natural form are the substandard raw materials which require modification.

The state of the surface of the activated and non-activated mineral powders, obtained by grinding in a ball planetary mill is presented in Fig. 1.

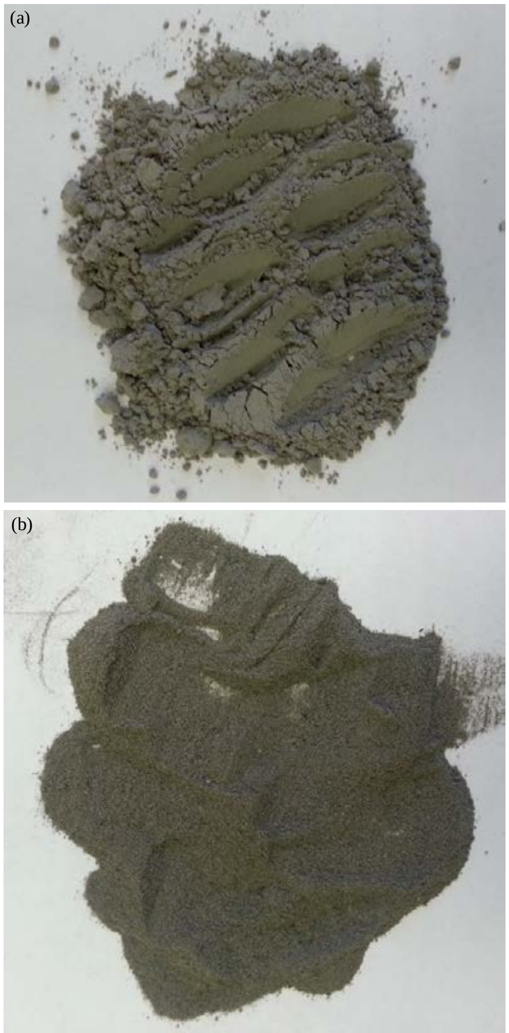

Fig. 1: The state of surface mineral powders; a) in non-activated state and b) in activated state

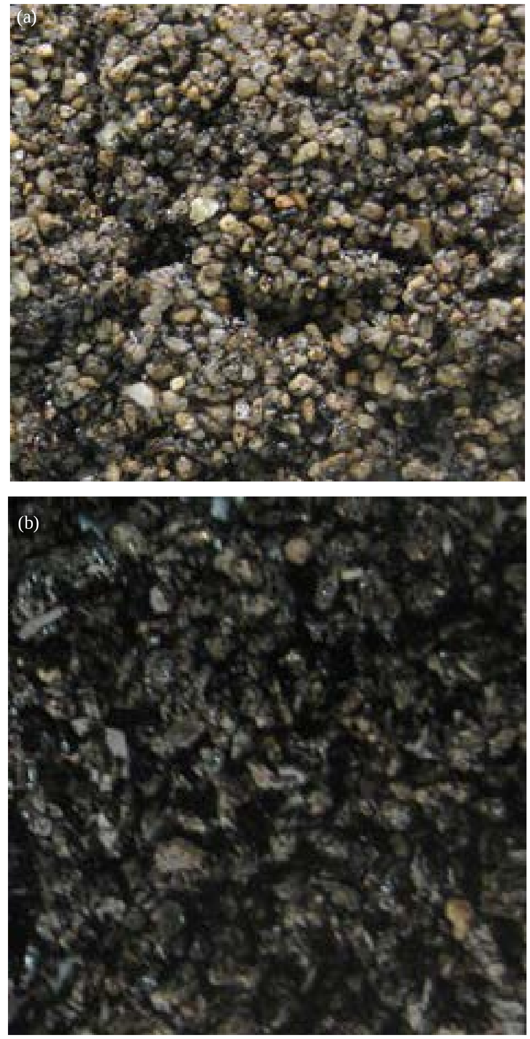

Fig. 2: Changing the adhesion of bitumen grade BND 60/90 with stone material; a) on non-activated filler and b) on the activated filler

From the presented Fig. 1, we can see that the particles of non-activated powder aggregate together, forming clumps while the powder, modified by stearic acid, is loose filler. At that the stearic acid as a surface-active substance, adsorbs on the fresh surface of the powder particles, formed as a result of their grinding with breaking their electrovalent bonds, envelops its particles, thus reducing the force of attraction (surface energy) between them and lowers the degree of agglomeration or eliminates it. This facilitates its transportation, storage and application. The specified property obtains the special importance in the conditions of modern technology of asphalt mixtures preparation, providing for the supply of mineral dust in asphalt mixing machines in the cold.

The obtained activated mineral powder has the properties of hydrophobic material and is practically not wetted by water. At that there is a significant increase of adhesion activity of bitumen in relation to a mixture of stone materials, containing the activated mineral powder (Fig. 2).

CONCLUSION

It is important to note that the comprehensive use of waste of such large-scale industries as mining and smelting complex in the conditions of production is the task of the further development of mankind. Because after the removal of man-made materials to the dumps and filtration fields, they become sources of dust and gas pollution in the working area of production facilities and in the atmosphere; penetrate the lithosphere and the hydrosphere and due to migration through air and water are transported to long distances and thus lead to a deterioration of living conditions and health of the population living in these areas.

ACKNOWLEDGEMENT

The research was done within the framework of a state programme of the Ministry of Education and Science of the Russian Federation No. 1950 as well as the project of strategic development of Belgorod State Technological University named after V.G. Shukhov No. 2011-PR-146.

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