

Soil Stabilization Mechanism in Different Loamy Minerals

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Abstract. In this study, it was aimed to research and interpretation of interaction mechanism of stabilizer low-molecular organic complexes with phyllosilicates mineral ingredients of loamy soils. Model adsorbents were investigation by using infrared spectroscopy method. Cation capacity is proposed as the express-evaluation integral characteristic to find out efficiency level structuring of stabilized soil. Prognostic scheme at the usage of the ionic binders for stabilized a road soils with different petrofabric structure is developed. The results of this investigation can be used as a basis for creation of road-construction material with high-performance characteristics

Introduction

Over the past years, there is a tendency of increase of roads construction volume for comfortable, uninterrupted and all-year transport travel. However on some operation places there is deficit of the rock materials and it leads to transportation expenses increase and construction project total value growth. One of the main directions of innovative activities in road construction is increase of nomenclature of subsoil, local materials and industrial wastes for road construction enlargement. This is the way to achieve construction significant cost reduction.

The main difficulty is to achieve the strengths, durability and weather resistance of road pavement, not conceding to traditional one. Taking into account the accessibility of local stabilized loamy soils, it is the most attractive and practical way to use them in road bed basement.

Volume increase of roads construction in the short term makes it necessary to actual and promising researches concerning the improving of loamy soils by using inorganic binders and stabilizers. The purpose of these investigations is to obtain materials with necessary strength, durability, water- and frost resistance.

A lot of science schools developed new methods to obtain soil-concrete compositions. For example, Bezruk V.M. [1] investigated the using of inorganic binder, and Birula A.K. [2] investigated the using of organic binder for soil stabilization. Analysis of their results showed that compounds on the inorganic binders basis is noted by high ruggedness, has low ultimate tensile strain and high cracks formation. Using organic binder, on the contrary, results in wheel track formation and plastic deformation of road base. But, thus far, clay rocks mineral composition influence on soil-concrete technical and operational characteristics was not adequately explored

Cement usage in soil-concrete making is connected with low water resistance of clay rocks, and it result to over-consumption of binder [3]. Combined stabilization with concrete and stabilizer usage is a one of the ways to solve this problem [4]. Up until recently plasticity index and grain-size distribution were accepted as basic characteristics used for soil-concrete mix composition, according to regulatory documents and soil stabilization recommendations.

Studies at the Belgorod State Technological University named after V.G.Shoukhov (BSTI) over the last 20 years showed that these data are necessary but insufficient.

Raw mineral material compositions influence on performance characteristics of soil-concrete on the basis of clay rocks of different Russian Federation regions is studied. Based on the results, it was found that not only genetic type, but minerals typomorphical peculiarities influence on the qualities of final composite. Above-mentioned fact was proved not only on natural, but also anthropogenic soils of different genetic types. As a binder were used both concrete, and lime and lime-containing wastes.

According to theoretical precondition, we can predict the stabilized soil quality with the account of clay rocks mineral composition depending on additive influence on mineral components.

IR absorption spectra as a result of stabilizer elements absorption in model systems

According to accepted hypothesis, rational structure material creation is possible by stabilization due to consolidating and hydrophobic effect of low-molecular organic complexes on aluminosilicate scaly component in the system “loamy soil – organic stabilizer” taking into account for mineral composition of different genetic types.

To understand the basic mechanisms of adsorption active molecular stabilizer complexes with real clay system was used to study the infrared spectra of the drug-treated model systems. Montmorillonite and illite- montmorillonite clay with kaolinite admixtures are provided as such model systems (Fig. 1, 2).

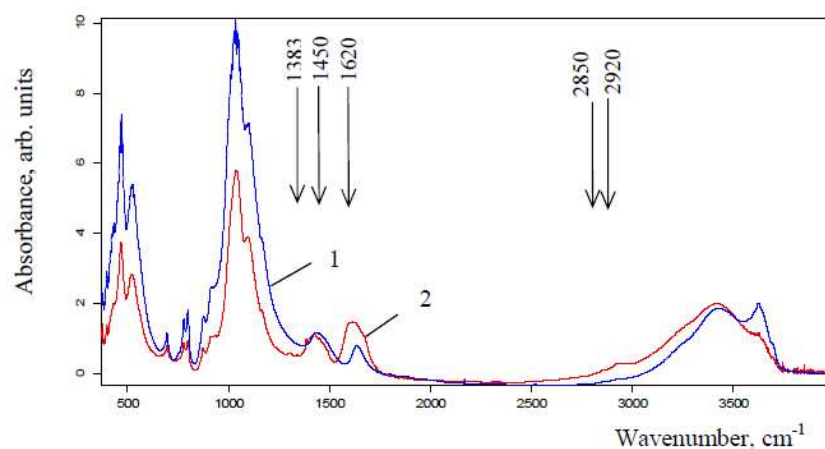


Fig. 1. IR absorption spectra of pure montmorillonite (1) and montmorillonite, treated with stabilizer (2)

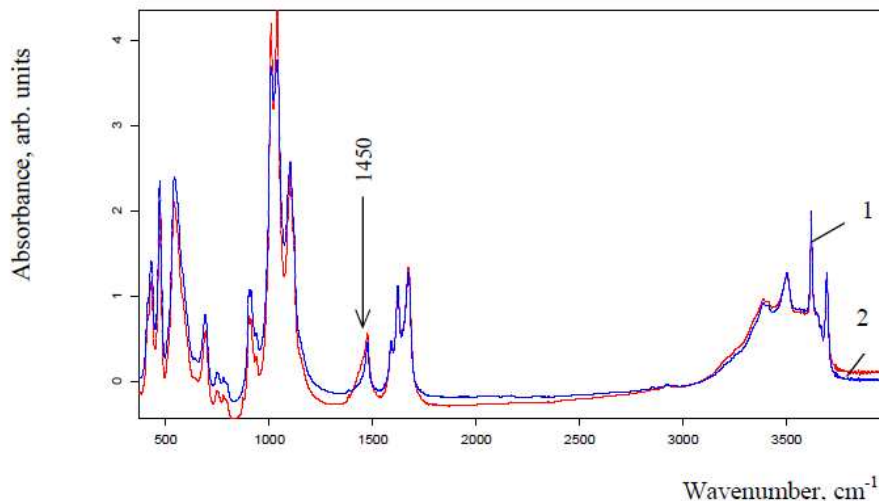


Fig. 2. IR absorption spectra of montmorillonite clay with kaolinite admixtures (1) and montmorillonite clay with kaolinite admixtures, treated with stabilizer (2)

Stabilizer on the basis of sugar-beet wastes in the form of bioactive oligosaccharide mixture (BAOM) was chosen as stabilize component of soil-concrete mixture.

Adsorbing BAOM molecule (spirits, amines, sugars, etc.) has active groups which let them intercommunicate with mutual hydrogen binding creation and with adsorbent active center.

Well-known correlations between absorption frequency and structure elements are in the basis of empirical interpretation of adsorption complexes spectrum [5, 6].

Interpretation of IR absorption spectra in the result of BAOM components absorption on the investigated adsorbents is difficult and complicated, because the stabilizer has multi-component system with different functional connections and water.

Drying out the solutions does not provide full water removal; the broad absorption band within the interval of $3000 - 3650 \text{ cm}^{-1}$ testifies this. In the same area there are superimposed narrow band stretching vibration of the free hydroxyl group OH, which is present in alcohol, mono-, oligo- and polysaccharides. And in the same area there is wide and intensive adsorption band, characterized intermolecular hydrogen binding of polyassociats.

Great number of different functional compound complicates the interpretation of the spectra of the stabilizer and, especially, of the products of its adsorption on the adsorbents. Hydroxyl groups can be removed out of adsorbents by heating at the temperature about $1000 \text{ }^{\circ}\text{C}$ during several hours. But the surface characteristics of adsorbents would be quite different, because these adsorbents have hydroxyl groups on the surface which are characterized by wide adsorption band in this frequency interval.

Correlation of main adsorption bands in the area of middle wave numbers with adsorption bands of molecular groups of materials, forming part of stabilizer showed that band 1383 cm^{-1} correlates to valence vibrations C – C groups, band 1450 cm^{-1} - deformation vibrations of groups C – C and C – H, band 1620 cm^{-1} - deformation vibrations of CH_2 groups.

It should be noticed that the number of bands increases with CH_2 chain growth, bands superimpose on one another. Bands 2850 and 2920 cm^{-1} corresponds to valence vibrations groups, containing C – O bonds. At that, the infrared spectrum of illite-montmorillonite clay before and after stabilizer treatment showed almost full match. The noticeable asymmetrical broadening towards the small wave number of absorption band profile 1450 cm^{-1} was exception.

Interaction mechanism of stabilizer organocomplexes with loamy individuals

Active low-molecular organic complexes interaction with loamy minerals is the subject to researchers' close attention, e. c. the paper of *F. Bergaya and G. Lagaly* [7]. However, despite essential success in creation of loamy-organic composites, many questions of organic complexes interaction mechanisms with loam polymineral formations remains disputable.

The crystal structure feature particularities of montmorillonite is the variable inter-unit-structure distance. Thus, monosaccharide molecules can be attached to the peripheral hydroxyl groups. On the one hand, it increases the mechanical strength of montmorillonite individuals, and, on the other hand, it blocks the ability of water molecules to the entrance to the interlayer spacings, thus increasing the hydrophobicity of montmorillonite clay [8].

The development of the binding properties of the stabilizer on montmorillonite clay can be interpreted as follows. The main components of BAOM are oligosaccharides, from monosaccharides to pentasaccharides. A characteristic feature of these compounds is the presence of outer group C-OH, which provides the potential ability of these molecules to «glue» the structural packages of montmorillonite. The montmorillonite crystal structure has a specific characteristic as follow. Only in silicon-oxygen tetrahedrons and aluminum-oxygen octahedrons on the nanocrystal border the oxygen atoms have non-compensated bonds, usually filled by attaching of hydrogen atoms. That is, the silicon-oxygen and aluminum-oxygen sheets are limited of hydroxyl groups on the montmorillonite crystal periphery in the *a*- and *b*- directions of the crystal lattice. Probably the oligosaccharides interact of outer hydroxyl groups with montmorillonite surface and form hydrogen bonds with the hydroxyl groups, which are located at the vertices of the peripheral silicon tetrahedrons (Fig. 3).

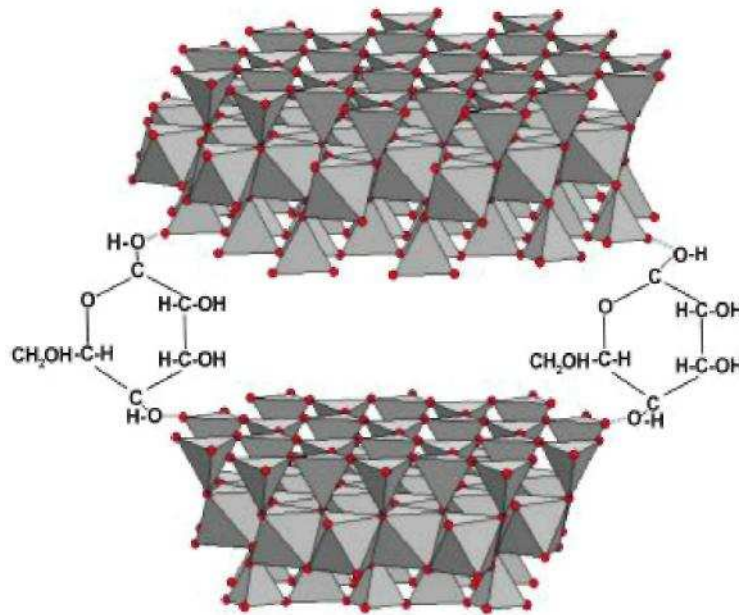


Fig. 3. The conceptual interaction scheme of montmorillonite with monosaccharide

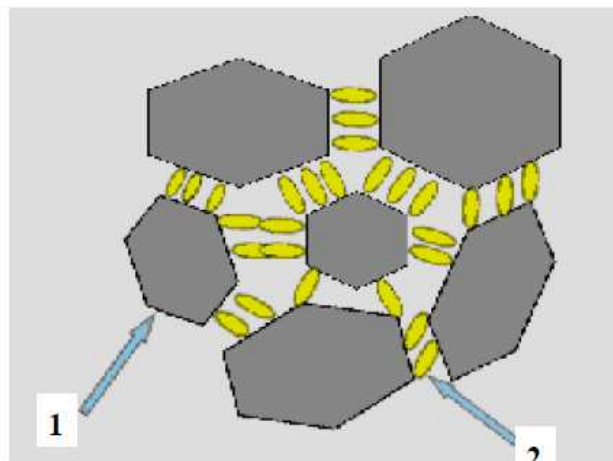


Fig. 4. The formation model of microcomposites: 1 - clay particles; 2 - low-molecular complexes

Asymmetric low-molecular organic complexes can interact with montmorillonite loams due to crystal-chemical characteristics of montmorillonite and by multivariate intercalation mechanisms with hydrophobization of its active components.

In both cases in inter-unit-structure space of montmorillonite the water molecules will be blocked or displaced, and it would increase the hydrophobization of the montmorillonite clays.

Besides, «glue» mechanism of neighbour 2D-microsized individuals by analogous interaction mechanism with nano- and microsized organo-montmorillonite composites creation is possible, too (Fig. 4).

Thus, the oligosaccharide can interact with the nanocrystalline montmorillonite individuals by periphery, interaction and nanocomposite interaction mechanisms.

Other mineral formations of clay soils, such as illite, kaolinite, mica, quartz and feldspar have a crystal- and dimensional features, so the interaction mechanism with active low molecular weight organic compounds differs from montmorillonite. Their interaction level is directly related to the concentration of active sites on the unit structural surface of these minerals. These characteristics are responsible for the realization of the possible interaction mechanisms of organic molecules with loamy soils. So, interaction level will increase in the line: montmorillonite -> illite -> kaolinite. It should be noted that this is entirely consistent with the values of cation exchange for these minerals.

Conclusions

On the basis of infrared spectrum analysis of loamy soils and interpretation of possible mechanisms of their interaction with low molecular weight organic compounds, it is established that structure formation of clay component of multimineral sedimentary rocks in the interaction with the stabilizer is that it block the active sites, and it resulting in cation capacity decrease and hydrophobization increase.

The influence character of clay minerals crystal-chemical features on the formation of stable organic-clay compound is determined, it is that in triadic interaction through hydrogen bonds by generalize scheme $[\text{Si}_2\text{O}_5]^{\text{IV}}[\text{AlO}_2]^{\text{VI}}[\text{Si}_2\text{O}_5]^{\text{IV}}$ - organic compound - $[\text{Si}_2\text{O}_5]^{\text{IV}}[\text{AlO}_2]^{\text{VI}}[\text{Si}_2\text{O}_5]^{\text{IV}}$ Efficiency level of interaction depends directly on structural and chemical nature of phyllosilicates. Cation capacity is the integral characteristic; its usage helps in express-evaluation to find out efficiency level structuring of stabilized soil. Proposed scheme is a prognostic basis at the usage of the ionic binders for stabilized high-performance road soils with different petrofabric structure.

Acknowledgments

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