Use of By-Products in Foundation Engineering

L'Utilisation des Sous-Produits dans le Génie de Fondation

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SYNOPSIS. The paper deals with methods of stabilization and improvement of steel-smelting waste products, that's open-hearth slag, and of wastes obtained sulphur ore treatment processes,that's water-saturated carbonate sludge. Some examples of utilization of fresh and dump slags in foundation practice are presented. It is given a method for desiccation of carbonate sludges by treatment with a non-uniform direct electric field which greatly improves their physicomechanical characteristics.

Open-hearth slags are rather rarely used in foundation engineering due to very slow processes of decomposition which lead to slags dilatation. But slag dumps and banks can be successfully used for bases of foundations after developing special methods either to stabilize the conditions under which slags do not expand or to eliminate decomposition of the slags into bases.

A good example of providing stable conditions for slag dumps is founding smelting shops on the dumps of open-hearth slags. The dumps age varies from 5 to 20 years, their thickness being 6-15m. As ground waters gradually go up, the lower slag layers about 2-8m in thick turn to be in saturated state during 7-10 years.

Slag compressibility was determined from model foundation ($2m^2$ area) tests with providing pressure in the toe of the foundation up to 0.8 MPa. Strength characteristics were calculated from shear tests. by building. The field tests have shown that open hearth slags in the aged dumps have the following characteristics: modulus of deformation E=30 MPa, angle of internal friction $\varphi=29°$, cohesion c=0.03MPa.

Swelling tests were performed on slags sampling from various depths. After drying the samples were placed at a given compactness into forms 15x15x15cm with a perforated bottom for water penetration. The forms were sank into a tank with water and swelling deformations of the plates were measured. These tests continued till full swelling deformations of the samples took place, but not less than 30 days. The slag was considered nondilatable at the relative swelling deformation $\delta_e < 0.05$ and it was considered to be dilatable at $\delta_e \geqslant 0.05$.

The tests have shown that slag samples gathered above ground water level do not expand while slags taken below ground water level have the ability to expand. This is caused by different state of inclusions of free lime on which slag structure stability depends. In aged slags lying above ground water the decomposition processes are already finished due to multiple wetting by atmospheric precipitation alternated with drying by air coming through pores. This resulted in loosening structure of grains and lime inclusions exposed to elements got fully decomposed.

The slags lying below ground water level did not undergo such processes, that is why some of inclusions of free lime inside the grains were not hydrated. While drying and under mechanical influences (sampling and compacting slags in the forms) lime inclusions were bared and under repeat wetting they showed the swelling ability.

The revealed features required to develope a special method of building of foundations below ground water level. It involvs groundwater lowering of the trench in the way to provide groundwater level 0.3-0.5m below the toe of foundations. Then slags were excavated up to the design level and foundations were constructed. During the works the slags were constantly wetted to prevent drying and thereby lime decomposition. The trench was backfilled with separated nondilatable open-hearth slags aged at least for 10 years in the dumps and taken above ground water. Slags in fills were compacted by pneumatic-tired rollers with wetting to 10-12% and providing dry density of 1850 kg/m3.

The way of using methods eliminating slag decomposition can be illustrated by an example of building a highway and tramway embankment from fresh open-hearth slags. The embankment about 70m wide (in the toe) and 10-15m high was built on silt. The lower layer of 6-8m thick was packed of 30cm loam layers compacted by rolling. The upper layer of 5-7m thick was filled with open-hearth slags according to the following method. First a core of aged steady-state slags 2m high and 15m wide was constructed on the loam surface in the middle of the embankment. Then fresh slags at 700-800°C were filled on both sides of the core and were watered to cool the slagsand to accelerate their decomposition. The cooled slags were stirred by a dragline arranging on the core surface. Watering alternated with stirring continued till slag structure became stable (according to laboratory tests). After planning the slags were compadted by rolling of 40 cm layers with

25t rollers, each layer being rolled 8-10 times to obtain dry density up to 1800 kg/m^3, thereby providing E=20 MPa, φ=25°, c=0.04Mpa and eliminating the slags ability to expand.

A more complicated method has been developed to make useful carbonate sludges obtained by sulphur ores treatment for bases and backfills. The sulphur ore treatment sludge comprises fine-grained material containing of up to 70% particles less than 0.1 mm in size. It consists of 87% calcium and magnesium carbonates admixed with surface-active agents and various chemical reagents. Water-saturated sludges are collected in tails where after 4-5 months their moisture content reduces to 38-45%. In three years after self-compaction moisture content becomes 30-32%. Then in spite of special drainage moisture content doesn't decrease because of low filtration (coefficient of permability $K < 10^{-7}$ m/s). Carbonate sludges have plasticity indes I_p=5-7%, cohesion c=0.005MPa, angle of repose φ_r =28° in dry conditions.

To stabilize and improve characteristics of sludges they were treated with non-uniform direct electric field. The operating voltage was supplied in the way to provide potential gradient increase towards cathode but differently in each layer. Another gradient crossed the gradient towards cathode and was formed by special electric equipment.

This method results in two times acceleration of dessication processes and in decreasing energy consumption in comparison with conventional methods of electroosmotic drying. When using industrial voltage of 0.4 kV and amplifying units of 400-600 A actual output is 12-18 tons per one installation. Additional treatment with time-inhomogeneous electric field during that the voltage is supplied intermittently according to a given programme allows to decrease power consumption by 30% at the same output for an installation.

The treatment of sulphur ore wastes with non-uniform in time and in space electric field results in intensifying the formation of coagulation and crystallization bounds, in decreasing humidity and in eliminating of its ability to thixotropy. After treating carbonate sludges have the following characteristics: moisture content W=7-10%, $K > 10^{-5}$ m/s, I_p =3%, c=0.05MPa, angle of repose φ_r =32-34°. There were two variants technologies of treatment in bases and fills.

According to the first variant carbonate sludge was kept in tails till its moisture content reaches 30-35%. Then the material was put into installations to be threated with non-uniform electric field as mentioned above to decrease humidity nearly to the point corresponding the plastic limit. The prepared material admixed with 4-8% of lime or any structure-forming agent was filled into bases of foundations and compacted by rolling or tamping.

According to the second variant carbonate sludges were treated with electric field directly in the body of the embankment. For this purpose on the planned surface of soil electric contact units were mounted. The electric units were filled with a 2-2.5m layer of sludges taken from tails without any threatment. Then the material treated with time-inhomogeneous direct electric field till its moisture content was 6-8% and the base became firm enough. This is an energy-consuming method in comparison with the first one, but it provides bases of high bearing capacity (up to 6-8 MPa).

The abovementioned examples prove the possibility to utilize various industrial by-products in bases and fills for engineering constructions under conditions that special methods are developed to stabilize the materials characteristics, and to ensure their high bearing capacity. Use of wastes in foundation practice results in reduction of cultivated lands disturbance, in sanitation of the environment and in broadening the variety of construction materials for bases, fills and embankments.