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GEOLOGICAL EXPLORATIONS AND LABORATORY TESTING AT THE SITE DESIGNATED FOR INSTALLATION THE VERTICAL GRAVEL DRAINS

Abstract

Vertical gravel drainages are used to improve the geomechanical characteristics of sedimented dusty and sandy soils where the application of gravity drainage is not possible. They are formed in a membrane made of a cylindrical woven geotextile (GEC - geotextile encased columns). They are intended to improve the geomechanical properties of the soil by lowering the groundwater level. Their practical application was realized on a part of an unstable internal landfill at the open pit of lignite "Drmno" in Kostolac. At the sites planned for the production of vertical gravel drains, it is necessary to perform the complex hydrogeological, geotechnical and laboratory tests, and this is shown in this paper.

Keywords: open pit, landfill, vertical drain, cylindrical geotextile

INTRODUCTION

It is known that water has a significant effect on the soil stability. Changes in the pressure of pores cause a change in the effective stresses in the soil, and as a result, changes in strength and stability occur. In coarse materials, lowering of the groundwater level is achieved by a gravity drainage, while in a fine-grained and dusty material the gravitational drainage is too slow and inefficient, and lowering of the groundwater level is most often achieved by a previous consolidation, caused by the load [2]. Drainage of low watertight soil is now increasingly being carried out using the geotextiles and other geosynthetics. Soil drainage is carried out in order to: stabilize slopes, reduce soil compressibility, increase soil load, prevent liquefaction and erosion.

The applicability of some methods of hydraulic improvement depends on a type of soil, i.e. grain-size distribution as shown in Figure 1 [3].

Improvement of geomechanical soil properties applying the pre-load method can be applied in all types of soil, but the best results are obtained in a soft, damp sand and dust. Preloading improves the working environment increasing the load and decreasing the compressibility of soft, unbound soil. The consolidation process is accelerated by construction the vertical and horizontal drainage [1].

The production of vertical gravel drainages in a membrane, made of cylindrical woven geotextile (GEC-geotextile encased columns), is a method of improvement the geomechanical characteristics of natural soil or deposited tailings and improving the conditions of drainage. By installation of gravel or sandy material, the mechanical properties of natural soil or defective tailings are enhanced (the overall strength parameters and the average modulus of deposited material compressibility) [2].

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Figure 1 Applicability of hydraulic improvement method

*Interpretation: 1 - electro osmosis, 2 - wells or vacuum wells,
3 - gravitational drainage too slow, 4 - gravitational drainage,
5 - necessary underwater works, 6 - use of large drainage pumps*

Vertical gravel drains (Fig. 2) allow water, located in the pores, to flow horizontally (radially) to the nearest drain (the horizontal path of drainage is the shortest path of drainage and amounts up to a half of axial distance between the individual drains), and rapid evacuation of water from the ground. Drainage reduces the pore pressures in the underlying ground, and therefore the substrate enters the drainage state, which positively affects stability.

Vertical gravel drains improve the mechanical characteristics of the soil (increasing the load and reducing the sagging) because a certain volume of soil is replaced by the gravel or sandy material with better mechanical characteristics. Geotextile prevents the "spillage" of the gravel into a low-load

material, i.e. allows the lateral fastening. It also provides a denser compaction of gravel, i.e. increase the average modulus of compacted material [5].

In addition, it prevents penetration of fine particles into the gravel, thereby reducing the watertightness and preventing the reduction of the average gravel strength that would result in the fine particles, deposited between the gravel. Vertical gravel drains can be mounted on a rectangular or triangular arrangement with a different axial distance. The installation diameter can be 600 or 800 mm. In our conditions, taking into account the costs and speed of installation, the vertical gravel drains can be made by drilling with a drill with a protective column as shown in Figure 3.

Figure 2 *Vertical gravel drains at the inner landfill of OP Drmno*

Figure 3 *Drilling using a drill with a protective column*

After the construction of vertical drainage (vertical gravel drains) and horizontal drainage (drainage carpet), new quantities of material are deposited. The newly-placed material with its weight plays a role of pre-loading and through the built-in drainage leads to the drainage of excess pore water the from natural soil or

deposited tailings. In this way, the geomechanical properties of the base soil are improved and, in general, it allows more secure laying of tailings or construction of various objects. Figure 4 shows the basic concept of applying the preload method by production of drainage on the internal landfill of the OP Drmno [4].

Figure 4 Basic concept of the pre-loading method with production of drainage
Interpretation: 1-soft ground, tailings, 2-improved soil, 3-vertical gravel drains, 4-excess pore water, 5-drainage carpet, 6-pre-load, deposited tailings

GEOLOGICAL EXPLORATIONS AND LABORATORY TESTING

On terrains for planned construction of vertical gravel drains, the preliminary hydrogeological and geomechanical explorations have to be carried out. For the purposes of defining the drainage and monitoring the fluctuations of groundwater level in the subject area, it is necessary to develop a network of observation piezometers for continuous monitoring a groundwater level regime over a period of one year. The main problem of preparation the piezometric network in the landfill space at the open pits is the inability to maintain the piezometer in a functional condition for a long time, because they are rapidly destroyed by operation of the mining machinery. Therefore, it is necessary to clearly mark the field on the ground after the construction of piezometers, and due to the continuity of the repository, it is necessary to plan their overtop to the required peak elevation. The locations of

piezometers should be determined on the basis of data from the previous exploration drillings, data obtained by the reconnaissance of terrain and dynamics of the mining machinery operation on disposal of tailings. Position of the placed vertical gravel drains on a part of the internal landfill OP Drmno is shown in Figure 5.

The exploration drilling is most often done by a direct method of diameter Ø146-101mm with constant circulation of working fluid. Drilling is performed from the beginning by a regular core pipe for continuous coring. A mild clay fume is used as the working fluid. During the drilling operation, the master driller runs a drilling journal in which the entire flow of work is recorded. The minimum percentage of core for the whole well should be 85%, with at least 75% in each drilling interval whose maximum length may be 6m. The core is stored in the wooden boxes with barriers 1m long.

Upon completion, the core should be photographed and the photos obtained are an integral part of the final documentary report. At the end of or during the construction of a drill hole, the extracted cores are

mapped and this work is performed by the geologists, i.e. a geologist for hydrogeology, a geologist for geomechanics and a geologist for mine geology in the presence of the Supervisor [3].

Figure 5 Overview the position of placed vertical gravel drains

During a detailed engineering-geological mapping of core of the exploratory drill holes, sampling of representative samples for testing in the laboratory is carried out, based on the preliminary macroscopic allocation of individual lithological environments within the terrain structure. Samples are taken from each material change or in an interval of 5m if the material was uniform. Length of an undisturbed sample is at least 30 cm. Samples are packaged in order to protect them from mechanical damage and shaking until their delivery to the laboratory. Untreated samples are packaged in the plastic foils. The samples should be delivered to the laboratory as soon as possible. With each sample, a label with the following data is placed: the designation and number of explored site – drill holes, locality, depth of taken sample, type of sample, type of test, date of sampling and name of responsible person as well as the observations entered in the field record in all, in accordance with SRPS U.B1.010 [3].

Laboratory tests of soil samples are carried out with a task of material classify-

cation, determining the parameters of strength, and defining the relationship of stress and deformation. Laboratory tests should be carried out in accordance with the natural conditions in the field.

The following laboratory tests should be carried out on taken samples:

1. Identification-classification tests
 - Determination the humidity of soil samples (SRPS U.B1.012)
 - Determination the volume of soil material by a cylinder of known volume (SRPS U.B1.013)
 - Determination the grain-size distribution (SRPS U.B1.018)
 - Determination the Aterberg limits of consistency (SRPS U.B1.012)
2. Testing the parameters of strength and deformability
 - Direct shear technique (SRPS U.B1.028). Testing the drainage shear strength after consolidation the test body up to $\sigma = 100; 200$ and 400 kN/m^2 , in all in accordance with SRPS U.B1.028. Based on the results

of this programmed experiment, the Coulombs linear envelope which shows the soil stiffness from the normal stress ratio and strength will be shown.

- Oedometer technique (SRPS U.B1.032). After placement, the test body is immersed in water and loaded to consolidation under the natural conditions, and then by step-by-step stress increase $\sigma = 25, 50; 100; 200$ and 400 kN/m^2 , in all in accordance with SRPS U.B1.032. The results are shown by a relative subsidence diagram and porosity coefficient change diagram.

Upon completion of exploration, the Final Report should be prepared including the following elements:

- name of a drill hole,
- description of used drilling technology and drilling equipment,
- angles and coordinates of a drill hole,
- photographs of a drill hole cores,
- lithological profile,
- report on the results of laboratory tests,
- construction of piezometers,
- signature of the Expert (Investor) supervision, Design supervision and Responsible contractor that they agree that the Report contains the minimum elements about a drill hole.

CONCLUSION

Hydrotechnical soil stabilization using the vertical gravel drains in a cylindrical woven geotextile is applied most in the cases of stabilization the soft and sedimented soil. An important task in the accurate locating of the zone for carrying out the construction of vertical gravel drains is to analyze the geotechnical and hydrogeological situation. In this regard, the complex hydrogeological and geotechnical exploration works as well as the laboratory tests are carried out at the

site. The obtained data from previous research are used for dimensioning the vertical gravel drains, and later for valorization of their drainage, and stabilization efficiency.

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