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Effect of Electro-kinetic consolidation on fine grained dredged sediments

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Abstract

The management of the huge amount of dredged sediments is an important issue to be solved worldwide, and dewatering is by far the most critical step when fine grained sediments are involved. Different technologies have been proposed in time to speed up the process. Even though electro-kinetic treatment is in principle one of them, it has not been implemented yet at an industrial scale, and only few trial applications are known. For such a reason, a multidisciplinary research activity is ongoing at the University of Napoli Federico II in the framework of the EU commitment ROSE with the aim to analyse the effectiveness and feasibility of such a technology from the lab to the site scale. In this paper, some evidences stemming from lab tests are presented. The results indicate that the application of low voltages improves the mechanical behaviour of the tested soil. In this case, however, the improvement is due more to a change in microstructure than to a decrease in void ratio.

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Keywords: Dredged sediments; dewatering; electro-osmotic consolidation

1. Introduction

Dredged materials are slurries composed by solid grains (from fine to coarse) and a large amount of water (depending on the adopted dredging technology), whose chemical characteristics depend on the dredging

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environment. Because of the shortage of disposal capacity, and the worldwide interest to tap the full potential of primary and secondary raw materials, dredged sediments must be considered as a resource [1] and many strategies and methodologies for their beneficial reuse are being developed throughout the world [2]. The typical treatment processes for contaminated dredged sediments are: dewatering; particles separation; contaminant destruction or removal and/or immobilization. The most employed mechanical dewatering techniques are: centrifugation, dewatering by belt filter press, plate and frame press, screw press. Electro-kinetic treatment is not usually considered, even though it may be beneficial for more than one of the treatment processes previously listed (namely dewatering and contaminant removal). A research program has been recently started at the University of Napoli Federico II to check if such a treatment may be considered as a feasible technology to dewater and improve fine grained dredged sediments at an industrial scale. To this aim, lab and site tests have been planned to check the effects of treatment on different soils. The paper reports and comments the first experimental results.

2. Electro-kinetic soil treatment

Electrokinetic soil remediation is a technology that has attracted increasing interest among scientists in the last decades, due to several promising laboratory and pilot-scale studies and experiments [3]. The principles of such a treatment method involve applying a direct current or low electric potential gradient to electrodes inserted into a saturated soil. When a current is applied to a soil, it stimulates the migration of electricity, pore fluid, ions and fine particles across the soil towards the oppositely charged electrodes, thus creating a combined effects of chemical, hydraulic and electrical gradients. In particular, an electrokinetic process goes through three phases: (1) electrophoretic sedimentation, (2) electro-osmotic consolidation and (3) electro-migration. Under an applied direct electric current, the polarized clayey colloids (with a negative charge on their surface) tend to migrate through the surrounding stationary liquid phase to the positive electrode (anode). This represents a dominant electrophoretic mechanism. On the other hand, the positive ions (cations) in the surrounding liquid and in the outer diffused part of the electric double-layer migrate towards the negative electrode (cathode), modifying the microstructure of the clayey particles. These cations mechanically drag with them the residual mass of free water, which results in a movement of liquid in the pores towards the cathode. This latter phenomenon, known as electro-osmosis, has been applied in soft clay engineering since the first successful field application by Casagrande in 1948 [4]. When the electric current is applied, another phenomenon occurs, named electro-migration, which involves transport of ionic species in the pore fluid, and can play an important role in the process of soil decontamination. The combined effect of the three previously mentioned electrochemical processes (namely electrophoretic sedimentation, electro-osmotic consolidation and electro-migration) results into a significant change in the physicochemical, hydrological and engineering properties of the soils [5]. For such a reason, the electro-kinetic treatment can be considered as a soil improvement technique [6] and has been used for the production of barriers for the containment of chemical pollutants, and sometimes even for the stabilization of landslides.

3. Experimental programme

Since the processes induced by the application of an electric field are both a reduction in water content and a modification of microstructure, it is of the outmost importance to check their relative importance from the ground improvement point of view. To this aim, two materials have been tested: one coming from the port of Gaeta, and the other one from the Basento river (Fig. 1a). The main physical characteristics of the two dredged materials are reported in Figure 1b, and clearly show that the Basento soil is finer and more plastic than the Gaeta one.

All laboratory tests have been carried out on remoulded specimens, obtained by drying the dredged material in stove at 105° and then mixing it with tap water to obtain an initial water content $w \sim 1.5\ w_L$. The oedometric tests were carried out in two identical floating oedometers designed to allow large displacements (maximum specimen height H= 20 cm, internal diameter D = 5 cm), having a non conductive stiff polimetilmetacrilate confining ring. Conductive porous stones were used both at the top and bottom bases of the specimen. In the electro-kinetic tests, the upper (anode) and the lower (cathode) end plates have been connected to a (DC) power supply, operating under constant voltage $\Delta\Phi$. The water is therefore electrically driven towards the bottom base. Mechanical and electric loads were applied following different loading and unloading paths, that can be classified as follows: mechanical (M), electric (E), and contemporary electric and mechanical (EM) paths. Different combinations were adopted as