International Journal of Offshore and Polar Engineering
Vol. 10, No. 2, June 2000 (ISSN 1053-5381)

Electrokinetic Strengthening of a Soft Marine Sediment

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ABSTRACT

An electrokinetic strengthening process is investigated in this study using a large-scale experimental facility. The results of experiments conducted on a marine sediment recovered from the Korean coast showed that the undrained shear strength, preconsolidation pressure and undrained modulus of the sediment were increased considerably in areas surrounding electrodes after the application of voltage gradients in the range of 9.5 to 28.2 V/m for 22 to 34 days. It was also evidenced that improvement of soil properties is further enhanced with time after the voltage was withdrawn. This paper presents the design, execution and results of the experimental program. The discussion covers practical issues such as the layout of electrodes and prefabricated vertical drains, application of intermittent current, power consumption and anode corrosion, monitoring of soil deformation and pore water pressure during treatment, and the geotechnical, physical and chemical properties of the sediment before and after treatment. The process developed in this research has potential applications of strengthening soil around foundations for new offshore structures as well as for the rehabilitation of existing platforms under various loading conditions.

INTRODUCTION

The application of direct or alternating currents in soil generates the electrokinetic process, including electro-osmosis, electrophoresis and dielectrophoresis. The process results in the consolidation and strengthening of clayey soils if the electrical configuration is properly designed and the properties of the soil satisfy certain requirements.

The earliest applications of electro-osmosis were conducted by Casagrande (1948, 1949, 1952) in clayey silts. Bjerrum et al. (1967) employed electro-osmosis to stabilize an excavation in a very soft Norwegian quick clay near Oslo. They reported up to a fourfold increase in the average undrained shear strength. More recently, Lo et al. (1991) demonstrated in a field pilot test that the appropriate design of electrodes and polarity reversal eliminated pumping at the cathode. The soil shear strength increase was demonstrated as the expansion of the effective strength envelope and increase in the preconsolidation pressure (Lo and Ho, 1991). Therefore, the improvement in soil properties is permanent. The permanence of the improvement was further confirmed by Milligan (1994), who reported that the bearing capacity of 16.5-m-long steel H-piles installed in a varved clay remains unchanged 33 years after the electro-osmotic treatment. In all of these case histories, the soils that underwent electrokinetic treatment were of low salinity, typically less than 2 mg/*l*. For high-salinity marine sediments, it is reported in the literature that the electro-osmotic flow in soil is significantly decreased or completely diminished (e.g. Casangrande, 1949; Grey and Mitchell, 1967; Lockhart, 1983; Mitchell, 1993; Yeung, 1994).

Received July 1, 1999; revised manuscript received by the editors February 14, 2000. The original version (prior to the final revised manuscript) was presented at the Ninth International Offshore and Polar Engineering Conference (ISOPE-99), Brest, France, May 30-June 4, 1999.
KEY WORDS: Marine sediments, electrokinetics, soil improvement, shear strength, offshore foundations.

Soft marine deposits of various thickness are commonly encountered along the seacoast of many parts of the world. They are characterized by low shear strength and high compressibility, which poses foundation problems to coastal structures. Due to the increased construction activities in these areas, there is a necessity to improve the engineering properties of the marine deposits and accelerate the process of soil consolidation. In particular, in Yulchon on the southeastern coast of the Korean peninsula, a land reclamation project has been undertaken by the Hyundai Institute of Construction Technology. The reclaimed land will be used for the construction of a harbour for industrial purposes. The construction cannot proceed on the reclaimed land before it gains adequate bearing capacity, which may take years because of the presence of a very soft, silty clay layer up to 43 m thick. The surcharge preloading in combination with prefabricated vertical drains (PVDs) has been proposed to improve the soil properties. However, the lack of available fill material raises economic constraints and makes this method less feasible. Therefore, several soil-improvement techniques were investigated and evaluated, including chemical stabilisation, vacuum preloading and electrokinetic consolidation. The results presented in this paper, i.e. using electrokinetics in combination with surcharge preloading and prefabricated vertical drains (PVDs) to strengthen the Yulchon sediment, are part of the evaluation program.

This study investigates the response of Yulchon sediment to electrokinetic treatment using intermittent current and noninsulated electrodes. The objectives of this investigation originate from the practical engineering problems, i.e., to study an alternative method for strengthening Yulchon sediment. There are two major challenges when using electrokinetics to strengthen marine sediments: (i) excessive power consumption due to the high electrical conductivity of marine sediments, and (ii) severe corrosion of metallic anodes due to electrochemical reactions. These challenges are addressed in this study by means of the application of intermittent current. The results of the study conducted by Mohamedelhassan and Shang (1998) suggested that current inter-