Experimental Study of the Electro-osmotic Dewatering in Hangbag

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Abstract: In recent years, geotube began to be widely used in treatment of coastal reclamation projects. However, the dewatering of sludge in geotube is inefficient. In this paper, for improving dewatering efficiency and laying a basis for the further study of large-scale electro-osmotic dewatering in geotube, electroosmosis has been applied to silt dewatering experiments in small hangbag. By measuring the change of moisture content, electricity current, voltage and comparing with other experiments under different conditions, the following conclusions have been obtained: the electro-osmotic dewatering speed is much faster than the natural dewatering. The non-woven fabric bag is easier to dewater than the high strength fabric bag which is made by the company of Royal Tencate.

Keywords: Dewatering, electroosmosis, geotube, hangbag, sludge.

1. INTRODUCTION

Geotube is made from polymer fibers. It resembles a tube and has the function of filtration. It has a very high strength and the length can be up to 200m. The structure of geotube is very simple and economical, so it has been widely used in the coastal reclamation projects. In the late 20th century, some researchers began to study the application of geotube in sludge dewatering which is beneficial to environmental protection. Jack Fowler used geotextile bag filled with sewage sludge to study the effect of dewatering, the result indicated significant consolidation or reduction in the volume of the sludge [1]. George drew the conclusion that the sand is easier to dewatering than the sediment of harbor and the industrial ash in the hanging bag [2]. Muthukumaranet discovered that when filled with the same material, the flow is correlated positively with moisture content and the opening size of geotextile [3]. It is also important to find a way to shorten the period of sludge dewatering time for improving the utilization efficiency of land and adapt to the works of reclamation project at the intertidal zone. Worley added flocculants to the sludge to improve the dewatering efficiency [4]. The reclamation project in Tianjin, Chinese technicians used geotubes as foundation and dam as showed in Fig. (**1**). The geotubes were filled with diluent sludge and added flocculants to speed consolidation.

Electro-osmotic consolidation is mainly used in foundation treatment and there are lots of useful achievements about electroosmosis. Russian scholars Reuss was found the charged clay particles by experiments in 1809

Fig. (1). The geotube dams in coastal reclamation projects.

and then the academic community had made many studies on electro-osmotic consolidation and dewatering. Casagrande used electro-osmotic consolidation on the foundation pit drainage and slope stability for the first time [5]. In 1968, Esring first proposed the theory of one-dimensional electroosmosis consolidation of soil [6]. Hamir and others studied the different effect of electroosmosis by using different forms of EKG and the effect of reinforcing to soil by the electrodes [7]. Fourie discovered that the energy consumption rate of electro-osmosis experiment in laboratory is less than in project site, because the former size is smaller than the latter [8]. Shao-Chi Chien and others improved the electro-osmotic stress and soil shear strength by injecting saline into electro-osmotic samples [9]. Su Jin-qiang deduced the theory of two-dimensional electroosmosis consolidation of soil on the basis of Esrig's theory [10]. Chen Xiong-feng used the electro-osmosis method with the bottom

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sediment in Taihu Lake to study the relationship between moisture content, water output and energy consumption [11].

With the development of world economy, the request for the treatments of sludge and soft foundations or estuarine engineering has become higher and higher. In China, there are also some electro-osmotic dewatering technologies in project [12-15]. As Fig. (**1**) shows that the geotube was used in reclamation and sludge dewatering project. Fig. (**2**) shows the sludge dewatering experient. This paper attempts to improve sludge dewatering speed by applying electro-osmosis in dewatering experiments using hangbag. It has integrated dual functions as electro-osmotic dewatering and bag's wall dewatering. It studies the impact factors and effect of electro-osmotic dewatering in hangbag and lays a good basis for the further study of large-scale electro-osmotic dewatering experiments in geotube.

Fig. (2). Sludge dewatering by the geotube.

2. ELECTRO-OSMOTIC MATERIAL AND EXPERIMENTAL METHOD

2.1. The Material of Sludge

The sludge of these experiments was taken from the bottom sediment of XuanWu Lake in Nanjing. The grain sizes of the silt are extremely fine, most of them are finer than 0.05mm and the structure is very dense. The physical properties of sludge as showed in Table **1**. At the beginning of experiment, all the moisture content of sludge was diluted about to 150 percents with water as Fig. (**3**) shows.

2.2. The Material of Hangbag and Electrode

As showed in Fig. (**4**), there are two kinds of materials in this experiment. One is made from high strength fabric which is produced by the company of Royal Tencate in Netherlands. The equivalent aperture (O^{95}) of this material is 0.68mm. The other is made from non-woven fabric which is produced in China, the equivalent aperture (O^{95}) of this material is 0.11mm and its weight is 300g/m^2. The electrodes in this experiment are 8mm-diameter reinforcement bars.

Fig. (3). The sludge of Xuan Wu lake.

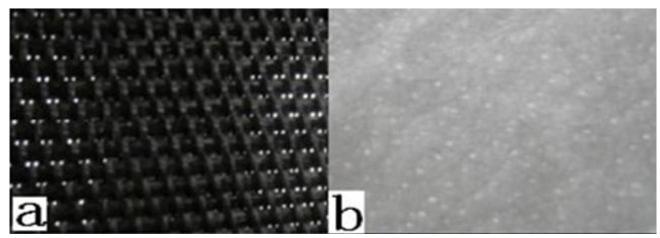

Fig. (4). The material of hangbag.
a. Royal Tencate high strength fabric **b**. non-woven fabric.

2.3. Experimental Method

In experiment, the diameter of hangbag is about 400mm. The actual effective height of the sludge in hangbag is about 400mm. As showed in Fig. (**5**), the cathodes are placed along the wall of hangbag. The anode is placed in the middle of hangbag. The value of voltage is 30V. The experiment lasted for 94 hours, because the effect of electro-osmosis dewatering is not obvious markedly in the late period of experiment. As showed in Fig. (**6**), there are five feature points in the different positions of sludge which are taken samples at different periods of experiment. The points 1 to 3 are set in the surface of sludge. Point 1 is near the anode. Point 2 is near the cathode. Point 3 is placed at the middle of the quarter circle. Point 4 and Point 5 are placed below point 3.

There are two parts of this test. The first part of the test is mainly used to study the process and mechanism of sludge electro-osmosis dewatering by electro-osmosis experiment in hangbag. The second part is mainly to set up comparative experiments under different conditions.

Table 1. The physical properties of sludge.

Specific Gravity	Moisture Content	Liquid Limit	Plastic Limit	Plasticity Index	Clay Particle Content (<5μm)
2.71	97.1%	74.3%	40.7%	33.6	48%

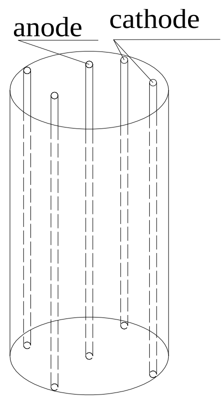

Fig. (5). The arrangement of the electrodes.

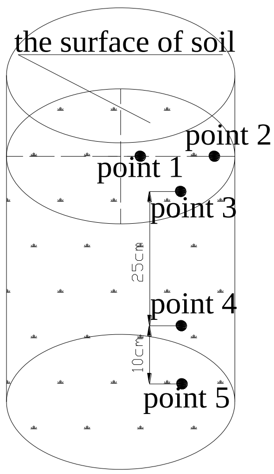

Fig. (6). The distribution of feature points.

3. EXPERIMENTAL STUDY OF ELECTRO-OSMOTIC DEWAYERING IN HANGBAG

3.1. Results and Discussion

Fig. (**7**) shows the changes of moisture content at the surface of sludge. As showed in Fig. (**7**), the moisture content of three points in the sludge's surface declined with time and the decline rate is decreasing with time. The effect of electro-osmosis dewatering was not obvious markedly in the later period of experiment.

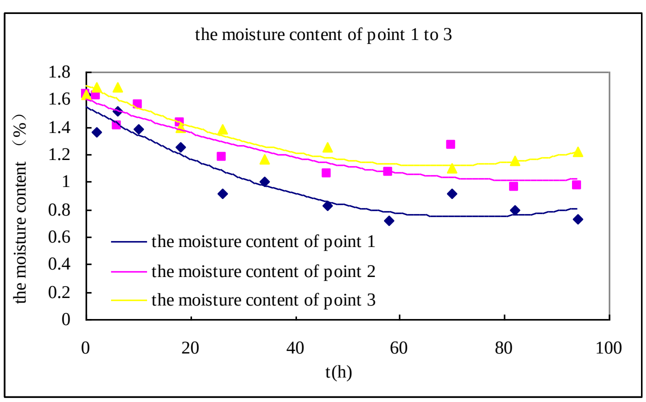

Fig. (7). The changes of moisture content with time at the surface of sludge.

There are two reasons for this phenomenon. On the one hand, with the electro-osmotic dewatering going on, the moisture content of sludge, the resistance of sludge became higher and higher, especially for the area near the anode. On the other hand, due to the shrinkage cracks near the anode caused by dehydration consolidation and the electrochemical corrosion on the surface of anode, the interfacial resistance between anode and sludge increases rapidly.

The moisture content of point 2 is situated between point 1 and point 3. This result means that the wall of hangbag has played the role of drainage boundary.

Fig. (**8**) shows that the total current changes with time. The total current shows an increasing tendency at the beginning of experiment and then decreased linearly. Based on observations, the water began to collect on the surface of sludge after 15 minutes. As a result, the total resistance between the electrodes decreased, so the total current increased correspondingly at the beginning of experiment.

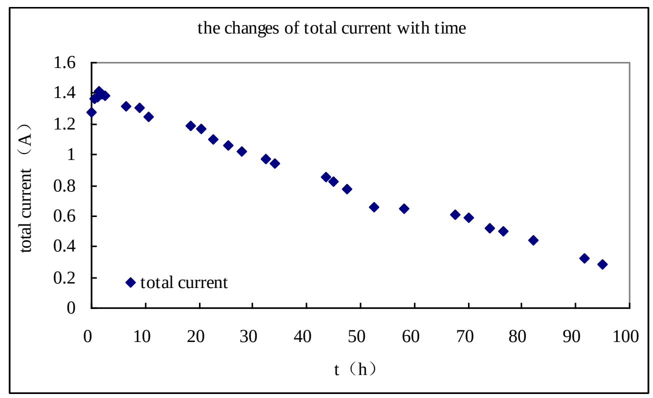

Fig. (8). The total current changes with time.

The process of electroosmosis in hangbag can be judged from the phenomenon. As showed in Fig. (**9**), the positive hydration cations are separated from the negatively charged soil particles and bring the water molecules moving by electric force. The soil particles sank down under the force of gravity and the water is finally concentrated to the surface of soil (Fig. **9d**).

In this experiment, the speed of dewatering from the wall of hangbag is slower than the speed of electro-osmotic dewatering, so the water is concentrated to the surface of soil, as showed in Fig. (**10**).

4. THE COMPARATIVE OF ELECTRO-OSMOTIC DEWATERING EXPERIMENTS UNDER DIFFERENT CONDITIONS

4.1. The Electro-osmotic Dewatering and the Natural Dewatering in Hangbag

4.1.1. Results and Discussion

Fig. (**11**) shows the changes of moisture content at the surface of sludge between the two groups. As showed in Fig. (**11**), the moisture content of the electro-osmotic group is declined with time, but the result of group without electroosmosis fluctuates around the value of 150% throughout the whole process.

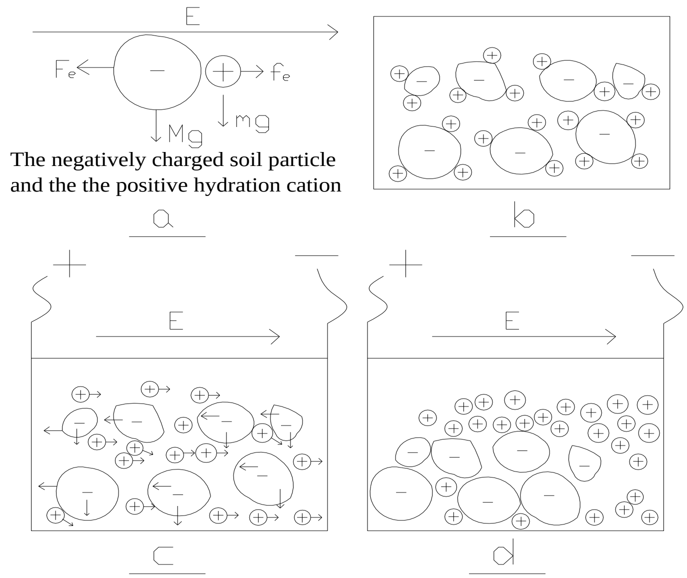

Fig. (9). The process of electro-osmosis dewatering.

Fig. (10). the phenomenon of water concentrating on the surface of sludge.

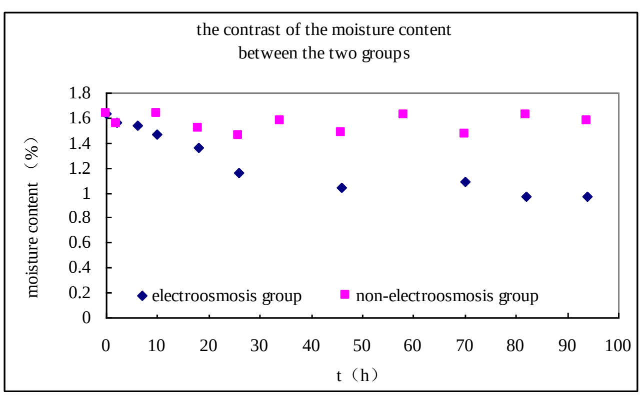

Fig. (11). the contrast of the moisture content between the two groups.

Fig. (**12**) shows the contrast of the total water output between the two groups. As showed in Fig. (**12**), the value of group without electroosmosis remains unchanged after 6 hours and the value of electro-osmotic group keeps growing. That means the effect of natural dewatering by gravity in hangbag is not visible.

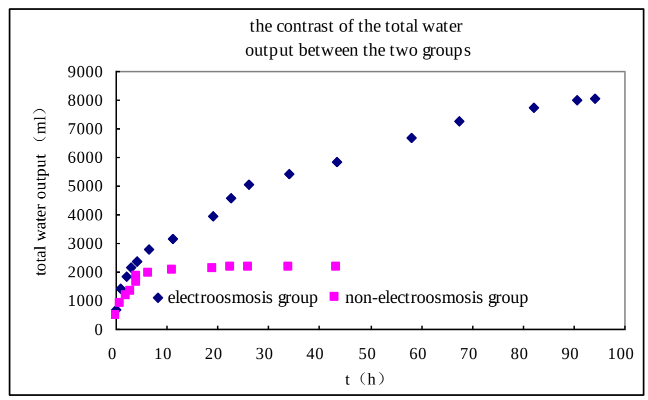

Fig. (12). The contrast of the total water output between the two groups.

4.2. The Comparative Electro-osmotic Dewatering Experiment between Two Different Materials of Bags

4.2.1. Results and Discussion

Fig. (**13**) shows the comparative of total water output changed with time between the high strength fabric bag and the non-woven fabric bag under the condition of electroosmosis. As Fig. (**13**) shows that the value of total water output of the high strength fabric bag is higher at the former period of experiment, but lower at later period of experiment.

This means that at the beginning few hours of the experiment, for the bigger equivalent aperture, the speed of water outputting of the high strength fabric bag higher than the non-woven fabric bag. At later period of experiment the high strength fabric bag was silt and can not dewatering very well.

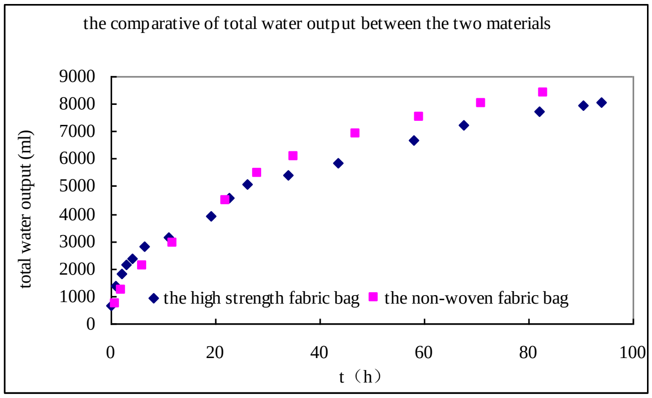

Fig. (13). The contrast of the total output water between the two materials.

5. CONCLUSIONS

This paper studied the effect of electro-osmotic dewatering in hangbag. Base on the analysis of moisture content and water output, the results indicated that the effect of dewatering for sludge by gravity is rather poor. But, the situation has become much better after combining electroosmosis. The high strength fabric bag was easy to silt and can not dewatering very well.

CONFLICT OF INTEREST

We have no conflicts of interest to declare.

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Declared none.

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