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Effect of Different Patterns of Electrodes on Electrokinetic Dewatering of Clay using Conductive Geotextile

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Abstract*— Excessive settlements could take place to structures build on clayey soils with high water content and low bearing capacity. The stabilization of these soils can be done by several methods such as, chemical stabilization, electrical stabilization, stabilization using geosynthetics, grouting, etc. The present paper use the process of dewatering using electro kinetics to strengthen soft soil using carbon rod as anode and a woven-knitted coir geotextile with mild steel as cathode. Electrically conductive geosynthetics combine electro kinetic phenomena with conventional geo synthetic functions. This work describes a study of the effectiveness of electrokinetic dewatering on clayey soil using conductive geotextile for 6 different arrangements of electrodes. A constant voltage of 30V is applied for 7 days to each of the models filled with clay at water content equal to liquid limit of soil. Test is repeated by varying the positions and number of electrodes fitted vertically to the sample in the model. From the results, optimum decrease in water content was by 32 percent, found in the set up with a tetrahedral pattern with 3 cathodes and one anode at the centre and maximum increase in unconfined compressive strength by 88.5 percent, found in the set up with tetrahedral pattern with 3 anodes and one cathode at the centre. The effectiveness of dewatering for all the experiments are evaluated based on the change in water content and unconfined compressive strength, to study the effect of arrangement of electrodes on electrokinetic dewatering using conductive geotextile. This electronic document is a "live" template and already defines the components of your paper [title, text, heads, etc.] in its style sheet.

Keywords*— Electrokinetic, dewatering, patterns, electro osmosis

I. INTRODUCTION

Soft and saturated soil with have high water content, leads to excessive settlements when a structure is built on it. Several methods are there to strengthen such soils such as, preloading, dewatering using sand drains, vacuum consolidation, chemical addition, etc. The major problem with additives relates to the time required for the cementing phases to form and gain strength. Also, the cementing phases may not be stable and may slowly dissolve as water percolates through the soil. Preloading is an effective technique, but it takes years to complete the action. For sand drains, the main disadvantage associated to it is the smear zone, and also the outer surface of sand drains will be blocked by the surrounding clay particles and thus its effect gets reduced as it depends greatly on the coefficient of hydraulic permeability. And, sand drains also takes couple of months to complete its action. Electrokinetic dewatering is much effective method which uses almost same energy consumption as that of vacuum consolidation and completes the action within a short period of time, when compared to other methods. It can compete with the cost effectiveness of other methods, if EK dewatering system is properly designed and also by using low cost materials as EKG material.

Electrokinetics and electro osmosis are techniques employed in manipulating pore pressure and plasticity indices of soils. These are becoming important technologies for soil reinforcement and environmental rehabilitation and geosynthetics are one of the means of introducing anodes and cathodes into a soil structure. The concept of electrokinetics is the use of current to induce water flow. This technique can be used in environmental remediation wherein contaminants are recovered or removed from soil by causing groundwater to flow to a collection point. Other geosynthetic applications are mine tailing dewatering and sewage (perhaps contained in geotextile tubes) dewatering. Sports turf is managed by using current to draw off excess water, or by reversing polarity, delivering water to plant roots.

The concepts of electrokinetics are applicable to slope stability, mechanically stabilized earth (walls), drainage and can result in cementation wherein ions precipitated from solution cement clays and the result is stiffer clays. An electrokinetic geosynthetic EKG, is a geosynthetic material, enhanced to conduct electricity, which can be used to transport water in fine-grained soils by electrokinetic means. The movement of current produces a net fluid flow toward the cathode. Electroosmosis is the movement of water resulting from the application of a direct current through porous medium. When an electric current is applied through saturated fine-grained soil between two electrodes, water contained in the soil migrates from positive charged electrode (anode) to the negative charged electrode (cathode). This results in dewatering and consolidation of the soil mass if the drainage is available at the cathode. The method can reduce the water content of the soil, thereby increasing its strength. Electroosmosis is a specialised technique and commonly used in very low permeability soils where groundwater movement under the influence of pumping would be excessively slow. Electro osmotic flow increases with decrease in hydraulic permeability of soil.

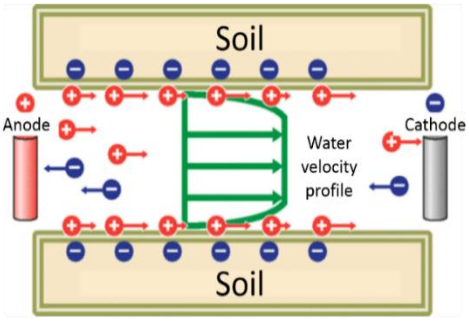

Fig.1 Electro osmosis

II. LITERATURE REVIEW

"Effect of soil type on electrokinetic dewatering of soft soils & slurries using conductive textile" by L. S. Thakur,T. K. Shah, D. L. Shah, D. A. Vasavada IGC, 2011:The paper used the process of dewatering using electrokinetics to strengthen various soft soils using a locally weaved conductive geotextile. Results were analysed based on water content and vane shear test.

"Laboratory Model Test on Improving the Properties of Soft Clay by Electrokinetics", by Eltayeb Mohamedelhassan, ISRN Civil Engineering Volume 2011: This experimental study was carried out in two test series to investigate the feasibility of decreasing the water content and increasing the shear strength and axial load capacity of laboratory-prepared soft clay by electrokinetic treatment.

"The Phenomenon of Electromigration During Electrokinetic Process On Expansive Clay" Soil by Nahesson Hotmarama Panjaitan, Ahmad Rifai, Agus Darmawan Adi and P.Sumardi, IJCEE-IJENS Vol:12 No:04, 2012: The ability to move and penetrate the soil layer deeply is one of the advantages of electrokinetic process. This research was conducted to find out the phenomenon of electromigration in expansive clay.

"Dewatering of Tunneling Slurry Waste Using Electrokinetic Geosynthetics" by D. Kalumba; S. Glendinning; C. D. F. Rogers; M. Tyrer; and D. I. Boardman 2009: Laboratory experiments were done to investigate the potential for using electrokinetic geosynthetics materials to dewater slurry waste from a tunneling operation.

"Evaluation of Various Electrode Configurations in Electro-Osmosis" by Sahib Amal Azad and Vinod P, IGC, 2010: The study uses different arrangement of a set of four electrodes to study its effect and the electrodes used were copper and its alloys.

Most of the studies focus on removal of contamination from soil. Studies on configurations of electrodes to make the process effective is scarce. This paper highlights on the role of different arrangements of electrodes on the effectiveness of electrokinetic dewatering process based on the water content and shear strength changes occurring on the treatment. The electrodes used are carbon and a combination of coir geotextile with mild steel.

III. OBJECTIVE

To study the effect of arrangement of electrodes on electro kinetic dewatering using conductive geotextile on the basis of changes in water content and shear strength of sample.

IV. MATERIALS REQUIRED

A. *Soil*

Experiments are carried out on Kaolinite clay (Sulekha clay factory, Thonnackal)

B. *Electrodes*

For all the experiments, a 10 mm diameter and 150 mm long carbon electrode are used as the anode and conductive geotextile is used as cathode. The conductive geotextile used is woven with coir fibre and steel filament. The steel filament makes the geotextile conductive.

Fig.2 Carbon anode and Coir-Mild steel cathode

C. *Power Supply*

An AC-DC convertor unit to supply a constant voltage of 30V for 7 days.

D. *Test Cell*

Laboratory scale models of same sizes are fabricated using 9 mm Acrylic-Silicon tank. The size of model is 27 cm x 20 cm x 21 cm with drainage outlets.

E. *Others*

4.75 mm passing and 2mm retained coarse sand for drainage purpose, Acrylic sheet, Filter paper sheet, flexible copper wire, etc.

V. METHODOLOGY

A. *Material Properties*

The properties of sample were found out for Specific gravity, Atterberg's Limit, Consolidation test, Unconfined compression test, Hydrometer, Free swell index and falling head permeability test. The sample was thoroughly mixed with water in liquid limit and kept closed for 24 hours for proper saturation.

B. *Experimental Setup*

Laboratory scale models of same sizes were fabricated using 9 mm Acrylic-Silicon tank. The size of model was 27 cm x 20 cm x 21 cm, with a filter chamber provided at a distance of 2 cm from the bottom using an acrylic sheet as a separator for allowing free flow of water during the process. Filter paper was placed over this partition to restrict the flow of any soil particles into the filter chamber which was filled with 4.75 mm passing and 2mm retained coarse sand. The tank was filled with the prepared wet sample. Electrodes are inserted into the sample at sufficient distance apart. Here, conductive geotextile (cathode) is placed after rolling its sheet. These electrodes were then connected using standard flexible copper wire to an AC-DC convertor unit to provide 30 V voltage for 3 days, 7 days and 14 days. Water content at 3 different depths (from top, at

7.5cm depth and at 15cm depth) were found out and also the sample was tested for its unconfined compressive strength for 3 days,7 days and on 14 days, to obtain the time period which gives the optimum result. The test is repeated with different configurations using 3 and 4 numbers of electrodes with a duration that gave the optimum results.

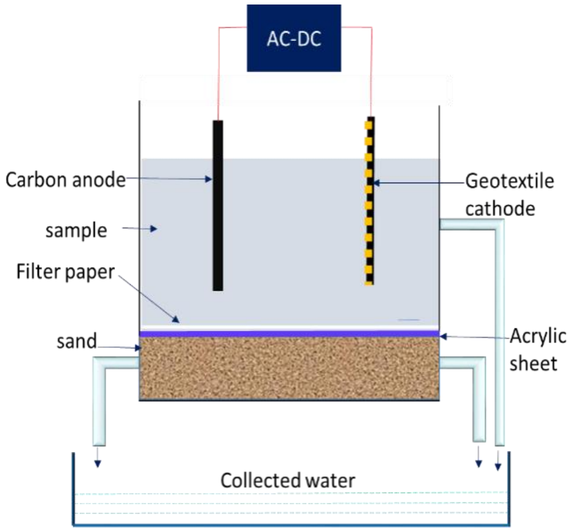

Fig.3 Experimental Setup

VI. PATTERNS OF ARRANGING ELECTRODES

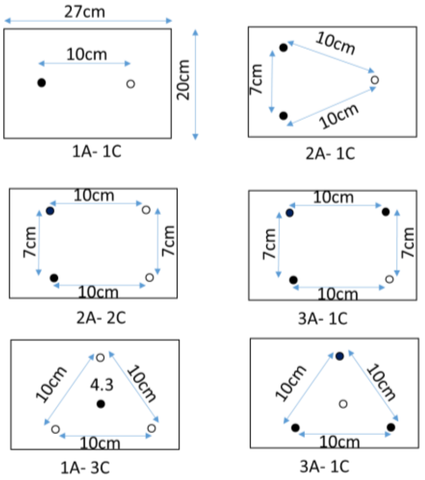

Fig.4 patterns of arranging electrodes

VII. RESULTS AND DISCUSSIONS

A. *Sample properties*

Table 1. Geotechnical properties of sample

Liquid limit	70%
Plastic limit	34.8%
Plasticity index	31.2%
Shrinkage limit	43.05%
Density	2.64 g/cm^3
Specific gravity	2.42
Percentage of clay	76%
Percentage of silt	24%
Coefficient of consolidation	0.0537cm^2/min
UCC strength	0.24 Kg/cm^2
Shear strength at failure	0.12Kg/ cm^2
Normal stress at failure	0.24 Kg/ cm^2
Cohesion of soil	0.12Kg/ cm^2
Free swell index, FSI	130
Coefficient of permeability	2.2 x 10^{-7}cm/s

B. *Experimental Results for duration finalization*

The results for finalizing the time duration for the experiments are given on table 2.

Table 2. Results for finalizing the time duration for the experiments

Pattern I	3days	7 days	14 days
Amount of water collected, Litres	0.3	0.6	0.4
Water content with depth, % 1. top of sample 2.At 7.5cm depth 3.At 15cm depth	 68 60 40	 66 50 35	 67 62 38
Unconfined compressive strength, q_u Kg/cm^2	0.55	1.222	0.9
Undrained shear strength, Kg/cm^2	0.275	0.611	0.45

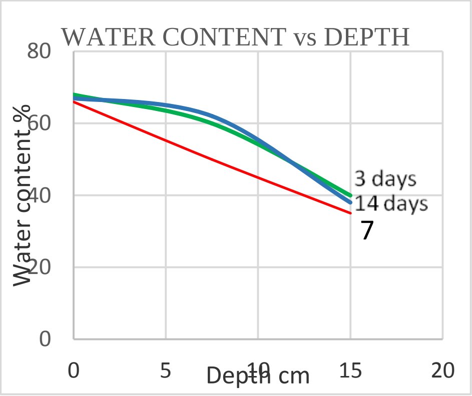

Fig.5 water content vs. depth plot

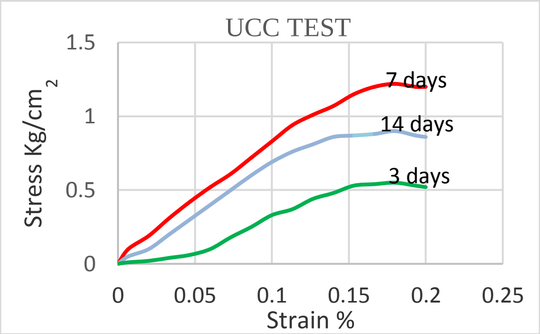

Fig.6 UCC plot

Average water content decreased by 14% by 3 days and by 19.7% by 7 days, but increased slightly after 7 days. Unconfined compressive strength and undrained shear strength increased by 56.3% by 3days and by 80.3% by 7 days, and the effect decreases thereby, shown in fig 6.

So the optimum results were obtained for 7 days and hence the duration for the experiments were fixed as 7 days.

C. Experimental Results for electrodes arranged in different patterns

Table 3. Results of experiments conducted for 7 days with different electrode arrangement patterns

Pattern	1	II	III	1V	V	VI
Amount of water collected, Litres	0.6	0.8	1.3	1	1.5	1
Water content with depth, %						
top of sample	66	65	62	63	62	62
At 7.5cm depth	50	45	39	42	33	41
At 15cm depth	35	32	22	29	19	28
Unconfined compressive strength, q_u Kg/cm^2	1.22	1.4	1.7	2	1.5	2.1
Undrained shear strength, C_u Kg/cm^2	0.61	0.7	0.85	1	0.75	1.05

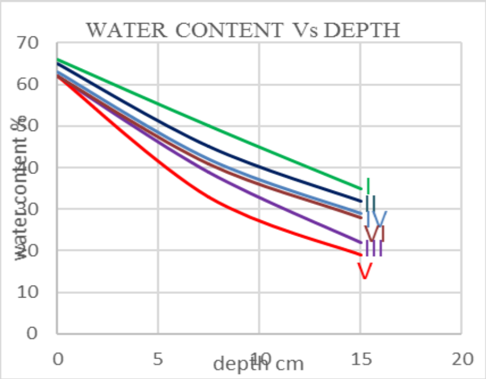

Fig.7 water content vs depth plot

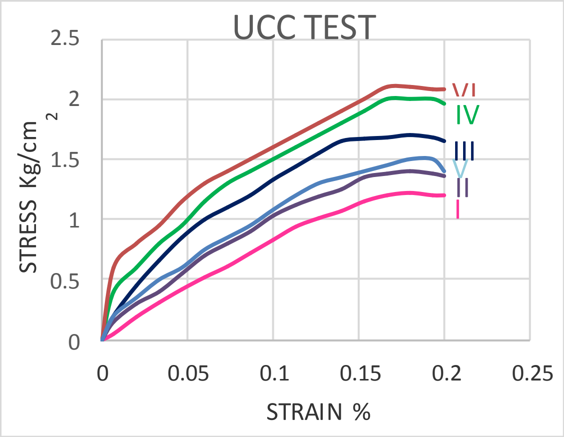

Fig.8 UCC plot

Table 3 shows the results of experiments conducted for 7 days with different electrode arrangement patterns. From table 1.3, it was found that, as the number of cathodes increases the effectiveness of dewatering increases, and discharge is also greater. Also, as the number of anode increases UCC strength increases. The plots for change in water content and unconfined compressive strength, after the treatment is shown in figures 7 and 8 respectively. The amount of water collected in pattern I was 0.6 L and as the number of electrodes increases more water was collected. The optimum result was achieved with the Vth pattern with 1A-3C tetrahedral pattern with anode at the centre and the water collected in this arrangement was 1.5 L. This is due to the increase in number of drainage points. Optimum decrease in water content was also achieved in Vth pattern with a decrease of 32%. The water content reduced with the depth to a large extend after the treatment and there was no significant change in water content towards the top in all the patterns. The optimum result for UCC strength was achieved with the VIth pattern with 3A-1C tetrahedral with cathode at the centre (88.5% increase in UCC strength).

VIII. CONCLUSION

As the number of electrodes increases in the limited space, significant changes are noted in UCC strength and water content of sample. The average water content of the sample after the EK dewatering tests was 38%.As the number of cathodes increases discharge increases and water content decreases. The significant decreases in the water content of the sample were found at the top of anode and center, whereas no significant change in the water content near the bottom was observed in the EK dewatering tests. The optimum decrease in water content (decreased by 32%) was achieved with 1A-3C tetrahedral pattern with anode at the Centre. The increase in number of anodes leads to greater UCC strength.

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