EFFECT OF SOIL TYPE ON ELECTROKINETIC DEWATERING OF SOFT SOILS & SLURRIES USING CONDUCTIVE TEXTILE

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ABSTRACT: The high water content in soils especially clays can loosen the bond of soil particles, resulting in low bearing capacity and high compressibility of the soils. Due to this excessive settlements could take place to structure build on such soils. Saturated soft soils can be strengthened by several methods such as dewatering or adding a suitable chemical. The present paper used the process of dewatering using electrokinetics to strength various soft soils using a locally weaved conductive geotextile. Electrically conductive geosynthetics (EKG) combine electrokinetic phenomena with conventional geosynthetic functions. This produces a range of geosynthetic materials which are able to effect physical and chemical changes to the properties of the soil, sludges, slurries and other materials in which they are placed. These “active” geosynthetics can be used in a range of applications including the civil and environmental industries; agriculture; mining and waste reduction; and the handling and the reduction of wastes and sludge. This paper describes a study using newly developed electrokinetic geosynthetics as electrodes for the in situ dewatering of different soils. A constant voltage of 15V was applied for 72 hours to each of the models filled with different soils at water content equal to liquid limit of soil. During the test, based on results of water content and vane shear strength noted periodically it is concluded that there is appreciable movement of water towards the conductive textile from where it was drained out and the strength of the soils increased noticeably.

Keywords: soft soils, dewatering, electrokinetics, geosynthetics, conductive.

INTRODUCTION
Soil present at many locations may be soft and saturated or, may have high water content, making it inappropriate for immediate construction use. Many industries produce waste in the form of slurries which are often transported to disposal sites. Conventional soil and waste strengthening typically involves the addition of cementing materials such as calcium hydroxide or Portland cement. The primary objective of strengthening is to produce a cementing phase such as calcium silicate hydrate, calcium carbonate or calcium sulphate. The major problem with additives relates to the time required for the cementing phases to form and gain strength. Additionally, the cementing phases may not be stable and may slowly dissolve as water percolates through the soil. Hence there is an economic driver to reduce the volume of these soils and waste prior to putting them to further use for construction. Developing rapid methods of soil strengthening is the need of the present day construction world.

A possible solution for these problems lies in the utilization of electrokinetics along with geosynthetics to dewater such soils and wastes. Electrokinetics and electroosmosis are techniques employed in manipulating pore pressure and plasticity indices of soils. Formerly hampered by difficulty in establishing suitable electrodes in soil structures, electrokinetics and electroosmosis are becoming viable 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. Anodes and cathodes are created from geosynthetics by using conductive materials such as carbon fiber, or by interlacing conductors (wire) in the textile. 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 polymeric geosynthetic material, enhanced to conduct electricity, which can be used to transport water in fine-grained soils by electrokinetic means. The basic EKG concept in dewatering slurries is to combine electrokinetic phenomena with the established functions of geosynthetics. Passing an electric current through a fine grained soil produces several different effects. The movement of current produces a net fluid flow toward the cathode. Ion and pole molecules will...
move in the electrical field. This will have the effect of reducing the water content of sludge and slurry in order to radically simplify their management and subsequent disposal/utilization.

MATERIALS AND METHODOLOGY

Soils
Experiments were carried out on five different types of soils and vermi compost (V.C.). Table 2 shows the source of procurement and the properties of the different soils used.

Electrodes
For all the experiments, a 10 mm diameter and 300 mm long carbon electrode was used as the anode and conductive geotextile was used as cathode. The conductive geotextile used was woven with polyester in wrap and steel filament in weft only. The steel filament made the geotextile conductive.

<table>
<thead>
<tr>
<th>Property</th>
<th>Place of Procurement</th>
<th>Code Name</th>
<th>Liquid Limit (%)</th>
<th>Plastic Limit (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flyash</td>
<td>Wanakbori</td>
<td>Soil 1</td>
<td>45.0</td>
<td>-</td>
</tr>
<tr>
<td>Bentonite</td>
<td>Bhavnagar</td>
<td>Soil 2</td>
<td>153</td>
<td>-</td>
</tr>
<tr>
<td>Yellow Soil</td>
<td>Vadodara</td>
<td>Soil 3</td>
<td>30</td>
<td>NP</td>
</tr>
<tr>
<td>Black Cotton Soil</td>
<td>Netrang</td>
<td>Soil 4</td>
<td>54</td>
<td>25</td>
</tr>
<tr>
<td>Yellow Clayey Soil</td>
<td>Sevasi</td>
<td>Soil 5</td>
<td>32</td>
<td>20</td>
</tr>
</tbody>
</table>

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Test Cell
Laboratory scale models of same sizes were fabricated using 9 mm waterproof plywood. The size of model was 26.5 cm x 20 cm x 20.5 cm, with a filter chamber provided at a distance of 1.5 cm from the bottom using an acrylic sheet as a separator for allowing free flow of water during the process. Wattman No. 42 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. Conductive geotextile was placed on acrylic sheet to act as cathode with the carbon electrode being place at a distance of 13 cm from the bottom to act as anode after the mould was filled with soil to its liquid limit. The electrodes were then connected using standard flexible copper wire to an AC-DC convertor unit. Various readings viz. ambient temperature, atmospheric humidity, current, humidity at surface and depth and strength were taken on daily basis at fixed time. 15 V voltage was applied to all the experiments. The duration for all the experiments was kept 3 days.

RESULTS AND DISCUSSION

Relative Humidity
Figure 1 to Figure 6 show relative humidity profile versus time for Soil 1 to Soil 6 respectively. For Soil 1 the humidity reduced with increase in time. The maximum humidity was observed at L2-D2 (52%) whereas minimum humidity was observed at L1-D1 (44%).

The maximum humidity was observed at L2-D2 (66%) and minimum humidity was observed at L1-D1 (58%) for Soil 2. For Soil 3 the maximum humidity was observed at L2-D2 (60%) and minimum humidity was observed at L1-D1 (54%) where as the maximum humidity was observed at L2-D1 (43%) and minimum humidity was observed at L1-D1 (31%) for Soil 4. Incase of Soil 5 the maximum humidity was observed at L2-D2 (52%) and minimum humidity was observed at L1-D1 (39%) while the maximum humidity was observed similar at L1-D2, L2-D1 and L2-D2 (52%) and minimum humidity was observed at L1-D1(52%) incase of V.C.
Reduction in Water Content
Figure 7 and 8 show the comparison of water content and percentage removal of water. For Soil the initial moisture content observed was 54.8 % and final moisture content was 50.64 showing a reduction of 7.591 % (Fig 8). For Soil 2 the moisture content decreased from the initial value of 153% to 146.23% as indicated by percentage water reduction in moisture content by 4.425%. For Soil 3 as shown in Figure 7 the moisture content decreased from 28% to 20.05% and percentage water reduction in moisture content was noticeable (28.39%).

For Soil 4 the initial water content observed was 47.6% where as the final water content was 41.56% and percentage water removal observed was 12.69%. The water content decreased from 33.27 kg/cm² to 21.38 kg/cm² showing a reduction of 35.73% in case of Soil 5. In V.C. the water content decreased from 0.56% to 12.21% showing 40.61% water removal.

Undrained shear strength
Figure 9 shows the comparison of vane shear strength with passage of time along the length as well as depth of the model on passing current through the experimental setup. For Soil 1, the strength increased showing a rapid rise between 6 hours and 30 hours followed by a gradual but significant increase throughout the experiment. The final strength noted was 0.063 kg/cm² at the end of 72 hours showing an overall 60.15 % increase in strength.

For Soil 2, a rapid rise in strength was observed in two steps between (0-6 hours) and between (30-54hours) followed by gradual increase in strength at 72 hours with final strength of 0.058 kg/cm² at the end of 72 hours showing an overall 109.125% increase in strength.

For Soil 3, the strength gradually increased upto 30 hours showing a rapid rise between (30-54 hours) followed by a gradual increase with the final strength observed were 0.045 kg/cm² at the end of 72 hours (overall increase in strength 136.84% ).

In case of Soil 4, after a gradual initial rise in strength (0-6 hours), a rapid rise (6 -30 hours) followed by a significant
gradual rise was observed up to 54 hours. Another rapid rise in strength was observed between (54-72 hours) with the final strength observed at 0.066 kg/cm² (102.5%).

For Soil 5, a gradual but significant increase in strength was observed up to 30 hours followed by a steep rise between (30-54 hours) followed by a gradual increase till the end of the experiment where the strength noted was 0.097 kg/cm² showing an overall 147.2% increase in strength.

For V.C., steep rise was noted in two steps i.e. between 0 - 6 hours and 54 - 72 hours showing gradually increased in the strength in between these two steps and the final strength observed was 0.053 kg/cm² (82.7%).

![Graph showing vane shear strength comparison](image)

**Fig. 9** Comparison of vane shear strength – Effect of dewatering material

The percentage removal of water from silty soil was higher as compared to black cotton clayey soil. Black cotton soil has a higher water holding capacity due to better bonding with water molecules and clay particles as opposed to yellow silty soil. This percentage decrease in water content correspondingly causes increase in vane shear strength of soil also. The removal percentage can be increased by increasing the voltage gradient rather than duration of test.

**CONCLUSION**

From the results presented in this paper, it is apparent that EK geotextiles are a suitable technology for dewatering EK responsive materials. Although the experimental set-up in the laboratory was rudimentary, there is still enough evidence to allow a number of conclusions to be drawn. The soil near the anode dried out appreciably. There is a significant volume and water mass reduction after EK treatment. The material is drier and non sticky, thus becomes easier to handle. Potential economic benefits in using EK dewatering as a treatment process are evident, however the economic saving is, as expected, largely dependent on the receptiveness of the material to EK treatment.

Although water molecules possess an overall neutral charge, they are polar i.e. they are attracted to ions in a solution and become oriented around these ions. Soil, as such is saturated with liquid containing ions in solution and when an electric field is set up within the soil, the positive ions tend to move towards the negative electrode. As the ions move, the surrounding water molecules are effectively dragged along and hence water moves towards the cathode. There are two factors associated with the above process, the first being need of some degree of conductivity otherwise the technique would be rendered ineffective. This opens a window of opportunity for applications in the dewatering of field soils. The second noteworthy issue is that the effectiveness of electrokinetic dewatering is virtually independent of the size of the pores within the soil being dewatered, indicating that, for a given voltage gradient, dewatering using electrokinetics can be expected to be just as effective in low permeability clay as in sand. In the latter case the technique would be redundant because its hydraulic conductivity is so high. For geotechnical engineers, who generally consider the achievable rate of dewatering being a function of soil type and in turn particle size, electrokinetic dewatering requires a change in mindset. It is the electro-osmotic permeability and the voltage gradient that are of utmost importance for electrokinetic dewatering in field.

**REFERENCES**