ELECTRO-OSMOSIS STUDIES ON KUTTANAD CLAY

[1]**Amal Azad Sahib**, Assistant Professor in Civil Engineering, TKM College of Engineering, Kollam (currently Research Scholar, IIT Madras). Email: azad52@yahoo.com
[2]**Dr. Bushra I**, Professor in Civil Engineering, TKM College of Engineering, Kollam. Email: bushrasheik@gmail.com
[3]**Rejimon G**, Instructor in Electrical and Electronics Engineering, TKM College of Engineering, Kollam

ABSTRACT: The Region of Kuttanad in the State of Kerala, India, is known as the rice bowl of Kerala. The region is famous for the black clayey silts and silty clays that it possess, which makes them quite suitable for agriculture. However this being a phenomenal area covering more than 1,100 sq km in the central Travancore region, is currently facing adverse issues following crop losses, infertility and settlement of structures. The presence of high water table also makes conveyance challenging for the residents of the area.
Various ground improvement techniques using lime, rice husk ash, cement, coir etc have been studied on Kuttanad Soil. Electrokinetic Stabilization has not been much studied in this region. In this context, this paper presents a few results based on the Stabilization of Kuttanad Clay using Electro-Osmosis; done in the laboratory using two moulds (30 cm x 30 cm x 30 cm and 90 cm x 90 cm x 90 cm). Copper plates of uniform shape and size were used as electrodes and various voltage gradients were applied across the soil mass contained between the electrodes. The process of each experiment using a particular voltage gradient at a particular spacing of electrodes yielded unique results that can be compared with the other sets of experiments. The soil was tested properties before and after the test. It was observed that with reduction in spacing between electrodes and increase in potential gradient, the undrained shear strength for treated clay is high. However on a large scale, an increased potential gradient does not give a proportionate increase in strength

***KEYWORDS**: Electro-Osmosis, Kuttanad Clay, undrained shear strength*

1. INTRODUCTION

Kuttanad Clay has gained much significance as a very soft soil with low bearing capacity and large compressibility values. Various researchers have studied the properties and reported large liquid limit and plasticity behavior, the presence of fossiliferous matter and the irreversible changes in its properties due to air drying through various sources (Ayyar, 1966; Suganya, 2013). Many ground improvement techniques have also been investigated (Bindu andVinod,. 2011, Mumthaz and Girish, 2014). Electrokinetic studies have been done on Kuttanad Clay in laboratory models. The authors (Amal and Bushra, 2014) had previously investigated with a set of four cylindrical copper electrodes of 1.5 cm diameter and obtained an improved undrained strength of around 20 kPa from a negligibly low value. Mumthaz and Girish, 2014, investigated using Electrokinetic Geosynthetics (coir geotextile woven with steel filaments), to obtain a maximum undrained shear strength of 14 kPa. In the present study, copper electrode sheets have been used to cover the entire width of soil to be treated.

2. ELECTROKINETIC PARAMETERS

Electro-osmosis is an established technique and has been investigated by many researchers (Bergado, et al., 2003; Chappell and Burton, 1975; Chew, et al., 2004; Golenko, 1971; Gray and Mitchell, 1967; Gray and Somogyi, 1977; Hamir et al., 2001, Lo et al., 1991; Rittirong et al., 2008; Wan and Mitchell, 1976). The treatment factors that contribute to the effectiveness of electroosmotic consolidation are: type of electrode, voltage gradient, polarity reversal, current intermittence, and duration of treatment.

Copper, mild steel and stainless steel in different shapes and forms have been used as electrodes. Electrokinetic geosynthetics (EKG) used in electroosmotic consolidation applications provide electrokinetic function in addition to the filtration and drainage functions. The EKG electrodes are less susceptible to corrosion due to the polymeric cover or treatment against corrosion

The voltage gradient used in field applications is typically in the range of 10 V/m to less than 100 V/m. The voltage gradient may be maintained constant throughout the treatment period or it can be varied over the duration. The polarity may be reversed by interchanging the anode and cathode, either with the same or higher voltage gradient. Voltage gradient can be held constant without interruption during the treatment period or can be applied intermittently in on-off pulses, for example 2 minutes on and 1 minute off. Current intermittence reduces the energy consumption of soil treatment.

3. PRESENT STUDY

The studies involved four phases. The first phase was the procurement and processing of the soil. Soil samples, in the disturbed state, were collected from Pulinkunnu, Alappuzha at 1m depth. For uniformity in the sample, it was subjected to air drying and further crushing. Soil passing through 2 mm sieve, was stored in large drums. The soil properties before treatment were tested for. The second phase involved the fabrication of the transformer and two set-ups, one a 90 X 90 cm acrylic box and the other a 30 X 30 cm acrylic box (fig 3.1 and 3.2). The third phase was Electrokinetic treatment. Soil sample was filled in both the boxes for a depth of 20cm .The initial water content of fresh sample was noted .Copper electrodes in the form of metal sheets were provided as anode and cathode. The tests were conducted in 90 X 90 cm box for 80cm, 60cm, 40cm and 20cm electrode spacings under a voltage gradient of 120V/m and 60V/m. In 30 X 30 cm box, the tests were conducted for 20cm spacing under voltage gradients of 120V/m, 100V/m, 80V/m, 60V/m, 40V/m and 20V/m .Electric current was continuously passed through the soil by using an adjustable DC transformer of capacity 4V – 24V until the water completely drained out. Water drained through the perforations of cathode was collected and measured. The fourth phase involved testing of the treated samples. Samples from stabilized soil were collected for conducting cone penetration test. After the tests, the results before and after treatment were compared.

4. RESULTS AND DISCUSSIONS

The results of basic properties tests are summarized in Table 4.1

Table 4.1 Basic properties of untreated soil

Sl. No.	Experiments	Results
1.	Specific Gravity	G = 2.04
2.	Compaction Test	1. Max Dry Density = 1.5 g/cc 2. OMC = 25.2
3.	Consolidation	Cv= 0.307x10-3 cm2/sec
4.	Hydrometer Analysis	1. % Silt = 55 2. % Clay= 4
5.	Atterberg's Limit	1. Liquid Limit = 37.47% 2. Plastic Limit = 20.32

4.1 Shear Strength results and analysis before and after Electrokinetic treatment

Before the electro-osmotic stabilization, the soil was allowed to undergo self- consolidation in order to differentiate the volume drained by self weight alone. A set of experiments were conducted on the 30 cm X 30 cm box for electrode spacing of 20 cm and another set on the 90 cm X 90 cm box for different spacings of 20,40,60 and 80 cm respectively. The results are shown in Fig. 4.1, 4.2 and 4.3

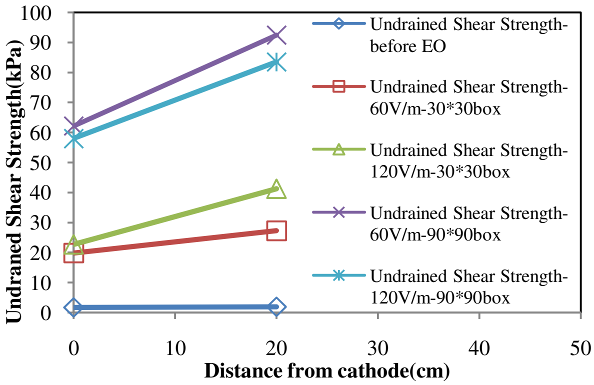
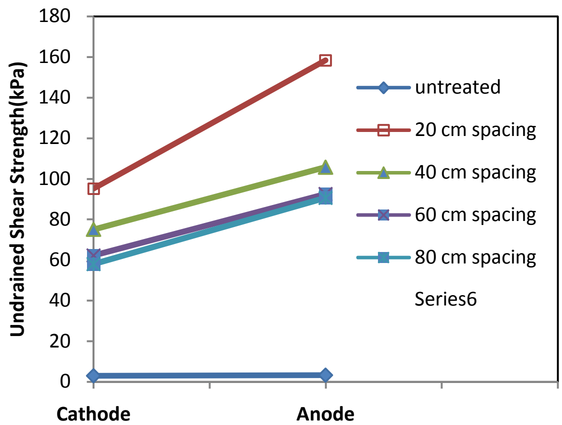


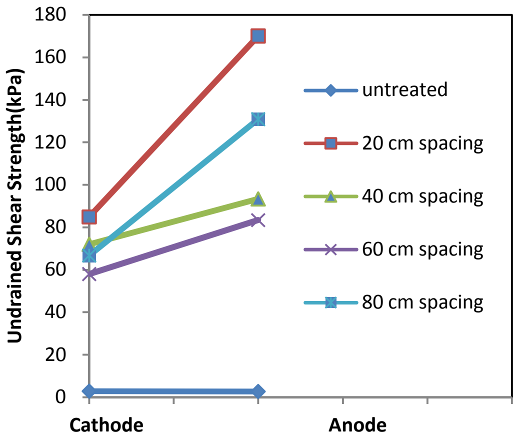
Fig. 4.1 Variation in undrained shear strength with distance from cathode for 60 V/m and 120 V/m potential gradients at a fixed electrode spacing of 20 cm, in 30cm x 30cm and 90cm x 90cm moulds

4.1.1 Effect of size of mould

With the same electrode spacing and Voltage gradient, when the tests were conducted in two moulds, the difference in strength value was around 2.25- 3 times. This can be observed in Fig. 4.1. In the 30 cm X 30 cm mould, the height of electrode projected above the soil surface is 10 cm and the contact area with soil is 30 cm X 20 cm, whereas in 90 cm X 90 cm mould, the projected height is 70 cm and the contact area is 90 cm X 20 cm. With increased electrode area, the resistance offered is less and flow of current is 3.25 times more. This is consistent with the increase in shear strength.



(a)



(b)

Fig. 4.2 Variation in undrained shear strength for different electrode spacings, in 90 cm X 90 cm mould for two potential gradients a) 60 V/m b) 120 V/m

4.1.2 Effect of voltage gradient and spacing of electrodes in undrained shear strength

From Fig. 4.2, it can be seen from the tests conducted on 90 cm X 90 cm mould that with increase in spacing between the electrode plates, the rate of increase in undrained shear strength reduces. On comparing the increase in strength between voltage gradients of 60 V/m and 120 V/m, the latter shows a higher increase (around 10 % more than 60 V/m) for 20 cm spacing of electrodes. But for all other spacings excluding 80 cm spacing, 60 V/m voltage gradient seems to be more efficient than 120 V/m in imparting higher shear strength. Therefore it can be seen that on a larger area, the advantage of using a higher voltage gradient is either not phenomenal or absent. This fact should be further studied while choosing the potential gradient for field applications.

5. CONCLUSIONS

Electro-Osmosis testing was found to be effective for all the tests conducted. With respect to the potential gradient applied and spacing of electrodes, a few conclusions may be made:

(i) With the same spacing of electrodes and same voltage gradient, Electro-osmosis was seen to be more effective by 2.25- 3 times, when the contact area of soil-electrode is more

(ii) While conducting the test on a larger area, a higher potential gradient does not substantially improve the properties relative to its lower gradients. Hence an optimum voltage, in this case appears to be 60 V/m, needs to be carefully worked out before field applications

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