

# Evaluation of Various Electrode Configurations in Electro-Osmosis

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## ABSTRACT

*Electro-Osmosis technology is a proven stabilization technique on fine-grained soils. When an electric field is applied to a mass of soil, the pore fluid moves from the region of anode to cathode along with the positive ions that move towards the negative electrode; the net effect being reduced water content and improved strength near the region of anode. From an elementary study, it was established that copper and its alloys form the best electrode material for electro-osmosis and that a uniform increase of resistance in soil during the process increases the efficiency of the process. Usually, application of this technique on field does not follow any particular configuration of electrodes. In this study, different patterns of arrangement of a set of four electrodes were implemented to study the effects of each of the arrangement. It was found that a tetrahedral configuration using one central anode and three cathodes resulted in better drainage of water by 33% whereas that with a central cathode and three anodes resulted in better improvement of strength by 76%.*

## 1. INTRODUCTION

Electro-Osmosis, as a soil stabilization technique has gained wide acceptance all over the world due to the mechanism of dewatering and improvement of strength that it renders to fine-grained soils. The fundamental processes namely electrophoresis, di-electrophoresis, electrokinetic migration and electro hardening assume their roles pertaining to various criteria such as conditions of the soil, presence of mobile ions, pH and length of diffused double layer.

The versatility of Electro-Osmosis has been established in many applications such as improving excavation stability (Chappel and Burton, 1975), decreasing pile driving resistance, increasing pile driving resistance (Hausmann, 1990), stabilizing soils using prefabricated vertical drains along with electrodes (Bergado et al., 2003).

In a previous study, the effectiveness of electro-osmosis was verified in processed Kaolinite clay. The type of electrode was varied by using Brass electrodes and Aluminium electrodes in each set of experiments. A predominant decrease in water content and improvement in strength were observed in the experiments. Also, Brass (alloy of Copper) electrodes were found to be more effective for Electro-Osmosis. It was found that a uniform increase in the resistance of soil during Electro-Osmosis, proved to enhance the impact of the technique.

The present study evaluates the various spacing arrangements of electrodes using a set of four Copper electrodes, for Electro-Osmosis. Two tetrahedral arrangements and one rectangular arrangement were implemented, to study and compare the different effects during electro-osmosis.

## 2. LITERATURE REVIEW

Due to its high compressibility, clay will consolidate and generate significant settlement when subjected to loading. This consolidation settlement causes detrimental effects on the overlying structures. Furthermore, with its low permeability, the clay takes longer to achieve primary consolidation. To solve this problem, the concept of dewatering becomes necessary.

Studies on electro-osmosis were started as long as a century ago. Various researchers have tried to determine the effectiveness of electro-osmosis on clays. Electro-osmotic transport of water through clay is the result of diffuse double layer cations in the clay pores being attracted to a negatively charged electrode or cathode upon the application of electric fields. Water molecules orient themselves around the ions in the pore space as water of hydration. As these cations move through the pore space towards the cathode, they bring with them associated hydration water or water molecules that clump around the

cations as a result of their dipolar nature. Consolidation results when water is drained at the cathode but not replaced at the anode. It has been proven to be effective in stabilizing and consolidating soils both in the laboratory and in the field (Chappell and Burton, 1975; Lo et al, 1991; Bergado et al, 2003).

The process has been applied to different types of soils, ranging from sensitive to soft clay and using various types of electro-osmotic cells. Though it has been found to be effective, the process has not gained wide acceptance due to the non-feasibility of the test set-up and electrodes to be used. But there is another school of thought that if a cost-effective and energy efficient design of the electrodes and the electro-osmotic cell is made, its enhanced use in stabilization of clays can be achieved (Shang and Masterson, 2000).

### 3. PRESENT STUDY

#### Electro-Osmotic Cell

The electro-osmotic cell, used for the study was made of acrylic tubing of 2 mm thickness. The dimensions of the box are 300 mm × 300 mm × 300 mm. The electrodes used for the tests were 200 mm in length and 5 mm diameter. A set of four electrodes were used in three tests. In the first test, two electrodes served as cathodes and two as anodes, their spacing being rectangular as shown in Fig 1. In the second test, one electrode served as anode and three as cathodes, their spacing being tetrahedral in fashion as shown in Fig 2. In the third test, one electrode served as cathode and other three as anodes, tetrahedral in spacing as shown in Fig 3. High voltage grease was applied along sides of the box to avoid short circuiting due to ingress of water.

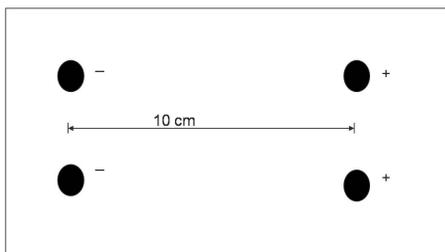


Fig. 1: Arrangement of Setup I

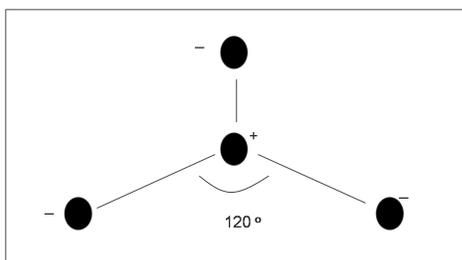


Fig. 2: Arrangement of Setup II

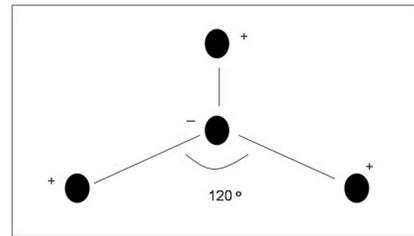


Fig. 3: Arrangement of Setup III

#### Soil

The soil used was Kaolinite clay processes from English Indian Clay Ltd. The properties of the clay are:

Liquid Limit = 70%,

Plastic Limit = 32%

Plasticity Index = 38%

Unconfined Compressive Strength = 5.5 kPa

#### Sample Preparation

The soil samples were prepared in a tray by mixing the soil in four batches of 5 kg each. The samples were mixed to liquid limit. The mould was filled in four layers. The electrodes were inserted in the suitable locations. Trenches and slight slope was provided for the drainage of water collected near the cathode regions. The mould was then placed in a tank of water, the level maintained at the clay surface. The sample was allowed to remain in the submerged condition for 2-4 days. The set-up is illustrated in fig. 4.



Fig. 4: Pictorial View of a Tetrahedral Setup

#### Testing

After two days of submergence condition, current was passed at a potential gradient of 120 V/m for a period of two days, until most of the water was drained. After the process was complete, the mould is taken out of the tank and subjected to various water content determinations and unconfined compression tests.

#### Results and Discussions

##### Stress Deformation Characteristics

The stress-strain characteristics improved and from a comparison of the three arrangements, it can be observed that third arrangement that consisted of three anodes, exhibited prominent strength behaviour by 76% over the other arrangements, as shown in Fig 5.

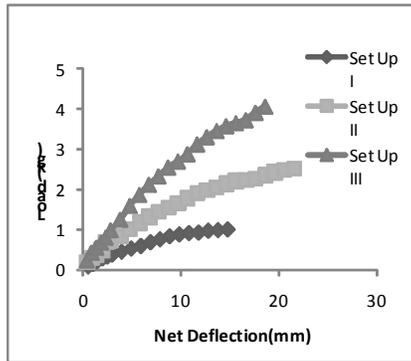


Fig. 5: Load Deformation Characteristics of Treated Clay

**Variation of Current and Resistance**

From Fig 6, it can be seen that the current reduced with time and resistance increased with time (fig 7). Variation of current and resistance were more predominant for the third arrangement. A uniform variation of current and resistance were also observed.

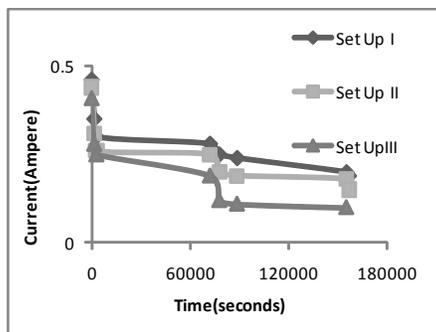


Fig. 6: Variations of Current with Time

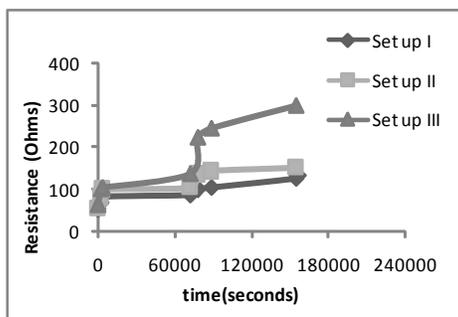


Fig. 7: Variations of Resistance of Soil with Time

**Drainage of Water with Time**

It can be observed from Fig 8 that drainage of water was a maximum of 1.2 L for the second arrangement which consisted of 3 cathodes. This is due to the fact that water collection was enhanced in the fixed interval of time with availability of more number of drainage points whereas the water drained in the case of third arrangement (900 ml) was least due to the lowest number of water collection points.

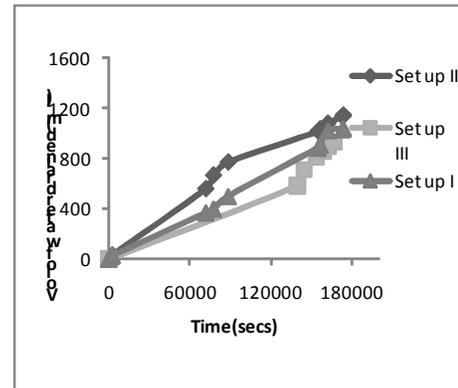


Fig. 8: Volume of Water Drained with Time

**Variation of Moisture Content with Depth**

The determination of water content of specimens taken from various locations and depths of the sample showed that water content of the sample reduced with depth from surface due to electro-osmosis. The second arrangement of electrodes with three cathodes showed better reduction in moisture content compared to the other two arrangements. (Fig. 9)

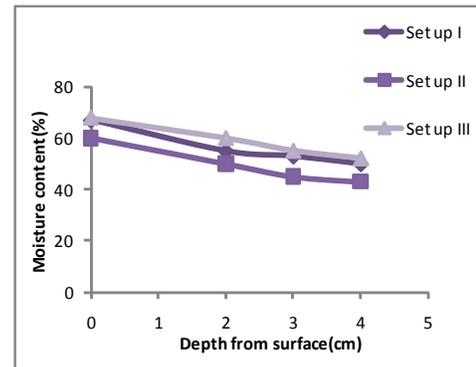


Fig. 9: Variations of Moisture Content with Depth

**4. CONCLUSION**

The advanced studies of Electro-Osmosis, studying the various configurations of a set of four electrodes produced significant results. The following specific conclusions can be made about the studies:

1. Tetrahedral spacing with cathode at center shows better strength characteristics by 76%.
2. Tetrahedral spacing with anode at the center shows better water drainage characteristics by 33 %.
3. A uniformly rated increase of resistance enhances the effectiveness of electro-osmosis.

The multifold improvement of soil characteristics by electro-osmosis thus, makes it a promising solution to better the properties of clayey and water-logged soils of Kerala state such as Cochin and Kuttanad.

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