Soil Stabilization by Electrokinetic Method

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Abstract: ***The application of chemical ground improvement using the electro kinetic stabilization (EKS) method has the potential to overcome problems in soft soil. The principles of EK treatment method involves applying a direct current or a potential gradient to electrodes inserted in the low permeable soils. The aim of this study was to evaluate the use of EKS as an effective method to stabilize soft clayey soil. The investigations were carried out in the laboratory using soil sample from locally collected clay soil. The cationic fluid used in EKS is calcium chloride ($CaCl_2$) and the electrodes used in this process are graphite and zinc. EKS of soft soil was done by using graphite electrodes as anode and cathode in first method and similarly combination of graphite and zinc electrodes as anode and cathode in second method. In above two methods of EKS the concentration of cationic fluid for each test run is 10, 15 and 20g/l of calcium chloride and the voltage maintained for each test run is 40, 50 and 60 volt for 3 hours. Electro kinetically stabilized soil was tested for liquid limit test, plastic limit test and swell index test. The results shows that the Liquid Limit was reduced up to 37.27% from 67.45%, Plastic Limit increased from 36.11% to 37.4%, Plasticity Index decreased from 31.34% to 13.73% and Free Swelling Index was decreased to 2.9% from 26%. The results showed that the Graphite – Graphite electrode combination was efficient when compared to Graphite – Zinc electrode combination.***

Keywords: Electro kinetic Stabilization, cationic fluid, Graphite Electrode, Zinc electrode.

1. Introduction

For many years, civil engineers are facing great challenges to design structures on soft compressible soils which include soft clay, silt and peat foundations. Consolidation of water-saturated, fine-grained soil occurs very slowly because the low permeability of these soils impedes the escape of pore water from the soil voids. Such soils have poor drainage and strength properties. Even under large temporary surcharge loads, settlement can take years because of this slow water movement and the great distance the water must move to exit the soil.

The aims of improving soils (as foundation and construction materials) are to increase strength, reduce distortion under stress, reduce compressibility, control shrinking and swelling, control permeability, reduce water pressure (redirect seepage), prevent detrimental physical or chemical changes due to environmental conditions, reduce susceptibility to liquefaction, reduce natural variability of borrow materials and etc.

Conventional remediation methods have been known successful in minimizing several damages, however they are expensive, time-consuming and may be difficult to implement in some existing structures. In this regard, electrochemical or electro kinetic (EK) treatment method can be used as an alternative soil treatment method for remediation of those deficiencies underneath building foundations, roads, railways or pipelines. The use of this technique involves an approach with minimum disturbance to the surface while treating subsurface contaminants and improving the engineering characteristics of subsurface soils. The use of electro kinetic treatment which is a comparatively new methodology is being investigated in some parts of the world for the potential application through several laboratory experiments to verify the versatility and effectiveness of this technique in practice as a viable in-situ soil remediation and treatment method. In present investigation an attempt has been made to stabilize clay soil by electro kinetic method using calcium chloride as cationic fluid.

2. Sample Collection

The soft soil sample was collected from Pallikaranai village, Velachery, Chennai. 25 bags of soil sample were collected of which 20 bags were used for the project. This particular site contained is full of soft clay soil. The soil samples were dried in sunlight and only fully dried samples were used for the experiments.

3. Analysis of Soil Properties

The collected soil sample was tested for basic soil properties. The tests conducted were specific gravity test, sieve analysis, hydrometer analysis, plastic limit test, liquid limit test, shrinkage limit test. The following are some of the tests done for finding the basic soil properties.

A. Specific Gravity Test

This test is done to determine the specific gravity of soil as per IS: 2720 (part 3) – 1980.

B. Liquid Limit Test

This test is done to determine the liquid limit of the soil as Per IS: 2720 (Part V) – 1980.

C. Plastic Limit Test

This test is done to determine the Plastic limit of the soil as per IS: 2720 (Part V) – 1980.

D. Jodhpur Mini Compaction Test

The Jodhpur mini compactor consists of compaction mold having an internal diameter of 79.8mm and internal height of 60mm and a capacity of 0.8litre.

E. Unconfined Compression Test

This test is done to determine the shear strength of a cohesive soil as per IS: 2720 (Part X) – 1970

4. Reactor Design and Treatment

The electro kinetic experiments were conducted in a laboratory environment at room temperatures. They were conducted in a cell comprising of three compartments: an anode compartment, a soil compartment and a cathode compartment. The cell was made of fiber glass with parallelogram shape open at the top. The box was 0.4 m long, 0.15 m wide and 0.16 m high. The fiber glass was 5 mm thick. The two outside compartments were reserved for the anode and the cathode chambers. The middle compartment was reserved for the soil specimen. The length of the middle compartment was fixed. The anode and the cathode compartments each contained one hole. The holes were used to wash out the anode or the cathode compartment and for removal of water being dewatered. Two types of electrodes were used for the experiments which were graphite and zinc. One set of experiments were performed with a pair of graphite electrodes and another set of experiments were conducted with graphite and zinc combination. The dimensions of the graphite electrode were 0.14 m wide, 0.165 m high and 5 mm thick and that of zinc was 0.14m wide, 0.165m high, 2mm thick. DC power supply capable of supplying maximum of 70 V, and 0-16 A was used.

Figure 1: Electro Kinetic React

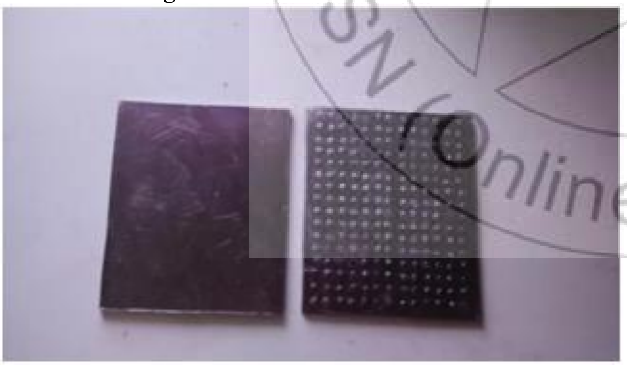

Figure 2: Graphite Electrodes

Figure 3: Zinc Electrode

5. Experimental Procedure

For each trial of experiments 2 kg of soil sample was used. It was mixed with 1100 ml of water. Calcium chloride was chosen as the cationic fluid. Experiments were conducted by varying the amount of calcium chloride as 10, 15 and 20 grams. Electrodes were inserted in the slits. The soil was filled in the middle compartment. Then the setup was switched on. The voltages were varied as 40, 50 and 60 volts during the experiments. During the experiment due to the electro kinetic phenomena dewatering takes place. The water was removed from the cathodic chamber through the holes.

Figure 4: Experimental Setup

6. Results and Discussions

a) Basic Soil Properties

The soil sample was tested for its basic properties before stabilization.

Table 1 Soil Properties before Stabilization

Soil Color	Grey
Liquid Limit	67.45%
Plastic limit	36.11%
Shrinkage Limit	16.58%
Plasticity Index	31.34%
Specific gravity	2.7
The maximum dry density	1.42g/cm2
The optimum moisture content	15.79%

Plasticity Index values for Graphite-Graphite Electrodes

The following graph shows the results of plasticity index for various combinations of Voltage and Concentration of CaCl2 using Graphite- Graphite electrode combination.

b) Soil Properties after Electro Kinetic Stabilization

The soil after stabilization was tested for its properties like liquid limit, plastic limit, swell index and plasticity index. The results are shown in graphs

c) Test Results with Graphite-Graphite Electrodes

1) Liquid Limit Values for Graphite-Graphite Electrodes:

The following graph shows the results of liquid limit test for various combinations of Voltage and Concentration of CaCl2 using Graphite- Graphite electrode combination.

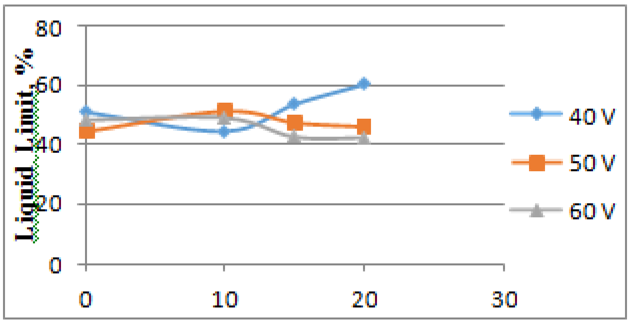

Figure 5: Liquid Limit Values for Graphite-Graphite Electrodes

2) Plastic Limit Values for Graphite-Graphite Electrodes

The following graph shows the results of plastic limit test for various combinations of Voltage and Concentration of $CaCl_2$ using Graphite-Graphite electrode combination.

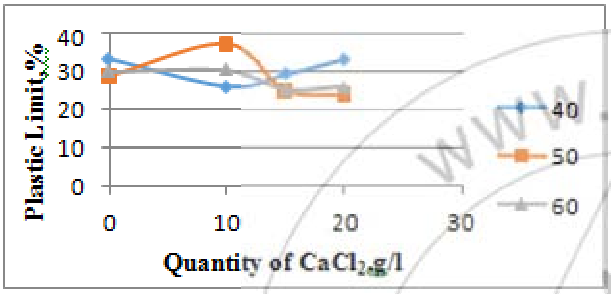

Figure 6: Liquid Limit Values for Graphite-Graphite Electrodes

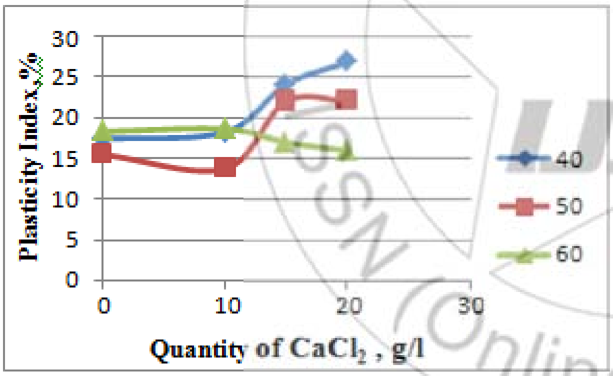

Figure 7: Plasticity Index values for Graphite-Graphite Electrodes

4) Free Swell Index values for Graphite-Graphite Electrodes:

The following graph shows the results of Free Swell index for various combinations of Voltage and Concentration of CaCl2 using Graphite-Graphite electrode combination.

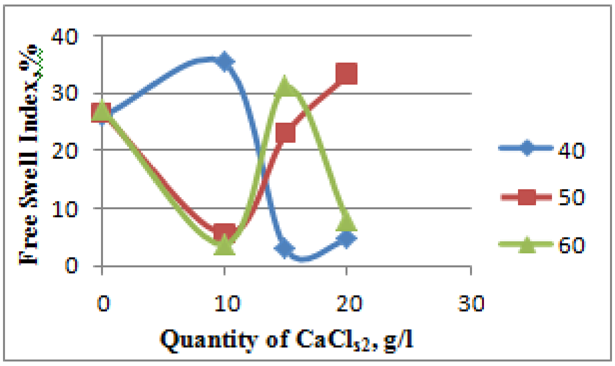

Figure 8: Free Swell Index values for Graphite-Graphite Electrodes

Test Results with Graphite-Zinc Electrodes

1) Liquid Limit Values for Graphite- Zinc Electrodes

The following graph shows the results of liquid limit test for various combinations of Voltage and Concentration of $CaCl_2$ using Graphite-Zinc electrode combination.

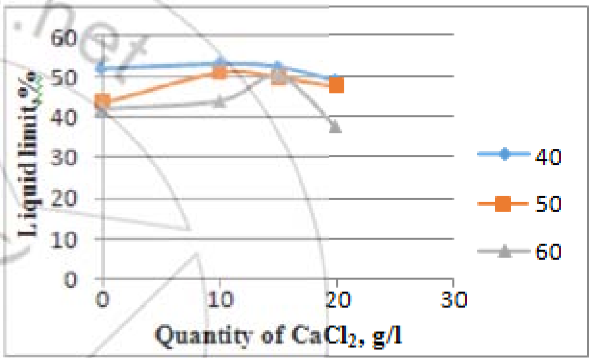

Figure 9: Liquid Limit Values for Graphite- Zinc Electrodes

2) Plastic Limit Values for Graphite- Zinc Electrodes:

The following graph shows the results of plastic limit test for various combinations of Voltage and Concentration of CaCl2 using Graphite-Zinc electrode combination.

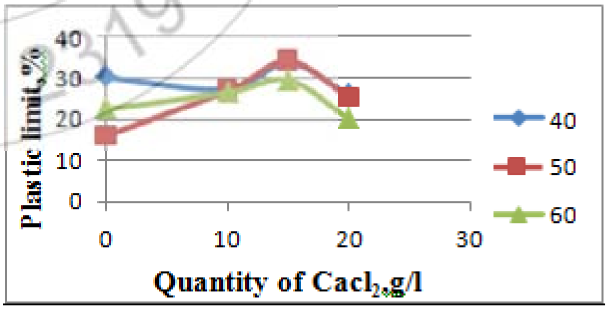

Figure 10: Plastic Limit Values for Graphite- Zinc Electrodes

3) Plasticity Index Values for Graphite- Zinc Electrodes:

The following graph shows the results of plasticity index for various combinations of Voltage and Concentration of CaCl2 using Graphite-Zinc electrode combination.

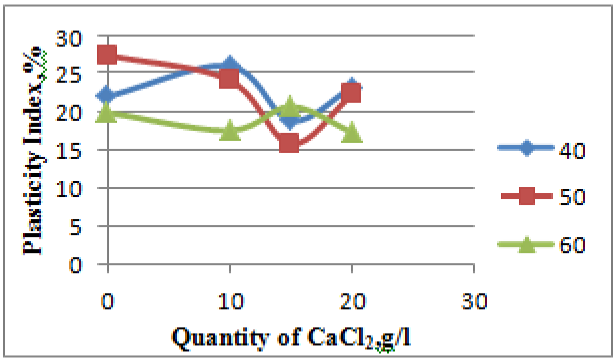

Figure 11: Plasticity Index Values for Graphite- Zinc Electrodes

4) Free Swell Index Values for Graphite- Zinc Electrodes

The following graph shows the results of Free Swell index for various combinations of Voltage and Concentration of CaCl2 using Graphite-Zinc electrode combination.

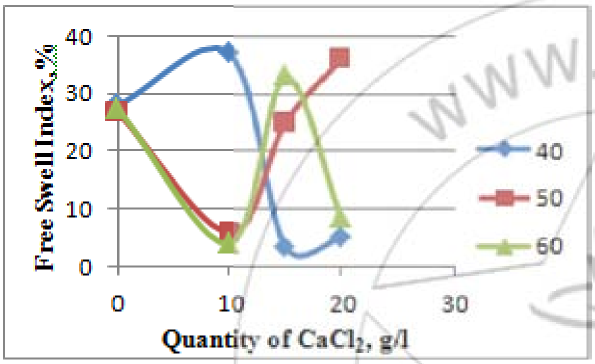

Figure.12 Free Swell Index Values for Graphite- Zinc Electrodes

7. Conclusion

In this study the plastic limit, liquid limit, swell index and plasticity index of the soil stabilized using calcium chloride as cationic fluid was investigated using two electrode combinations which were graphite- graphite and graphite-zinc. Based on the tests conducted the salient features are represented as follows.

- The results for liquid limit showed that lowest value of liquid limit was obtained for graphite-zinc electrode combination.
- The results for plastic limit showed that the highest value for plastic limit was obtained for graphite-graphite electrode combination with a voltage of 50 and 10g of calcium chloride.
- The results for plasticity index showed that the lowest value for plasticity index was obtained for graphite-graphite electrode combination with a voltage of 50 and 10g of calcium chloride.
- The results for swell index showed that the lowest Value for swell index was obtained for graphite-graphite electrode combination with a voltage of 40 and 15g of calcium chloride.
- From the study it was found that graphite-graphite Electrode combination gives best results for stabilization of soil using calcium chloride when compared to graphite-zinc electrode combination.

Table 2: Comparison between the electrodes

Particulars	Liquid limit, %	Plastic Limit,%	Plasticity Index,%	Free Swell Index, %
Initial Values	67.45	36.11	31.34	26
EKS using Graphite- Graphite Electrodes	42.14	37.4	13.73	2.9
EKS using Graphite- Zinc Electrodes	37.27	34.01	15.71	3.6

The efficient results of EKS given by using Graphite-Graphite Electrodes and Graphite- Zinc Electrodes are given. The results shows that the Liquid Limit was reduced up to 37.27% from 67.45%, Plastic Limit increased from 36.11% to 37.4%, Plasticity Index decreased from 31.34% to 13.73% and Free Swelling Index was decreased to 2.9% from 26%. From the above results it can be inferred that Graphite-Graphite Electrode combination gives efficient results compared to Graphite – Zinc electrode combination.

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