International Journal of Recent Advances in Multidisciplinary Topics
Volume 2, Issue 4, April 2021
https://www.ijramt.com | ISSN (Online): 2582-7839

Electro-Osmotic Consolidation of Expansive/Weak Soils at Nilgiris Region

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***Abstract*: The Mountainous region are proven to landslides each and every year around the globe. It causes huge loss in revenue and also destructs the life of a common man. It is mainly due to the soil present and also the destruction of the forest cover in that area which causes the landslides. To control it various methods are used and landslides are prevented all over the world. Here, The Electro-osmotic consolidation is a method, which is used and experimented and conducted in the highly landslide prone areas in Nilgiris. The present study investigates the type of area present and examine the soil properties before and after the consolidation process. The soil sample was collected and the properties were tested. The consolidation was done in the lab with the help of Graphite and Iron as the cathode and anode respectively with power supply of 5-7 V and the excess water is dispersed with the help of a weight. The soil properties were again checked and the results were satisfied with the reduction of water content and undisturbed organic matter. It is concluded that the soil consolidation was economical and induced sufficient strength.**

***Keywords*: Anode, Cathode, Electro osmotic consolidation, Graphite, Iron, Soil stability, Voltage.**

1. Introduction

Electro-osmotic consolidation, was studied and applied for the first time by Casagrande. It is an attractive soil improvement technique for soft clay/weak soils. In this technique, the soil is consolidated by the application of electric current. The consolidation is the process in which the volume of soil changes constantly with respect to change in pressure. In this type of soil, normal consolidation consumes more time due to low shear strength. In order to overcome this issue, Electro Osmotic Consolidation technique is best one and cost effective also. The volume of water squeezed out is faster in the Electro Osmotic Consolidation technique when compared to normal consolidation. This process is efficient in low permeability clays in which the electro osmotic permeability is greater than the hydraulic permeability. The consolidation period can be reduced effectively by applying Electro Osmotic technique.

Electro-osmotic consolidation can be a viable technique to drain, consolidate and strengthen saturated fine grain soil. Electro osmotic consolidation is the usage of anodes and cathodes and to develop a negative pore water pressure which creates an expulsion of water from the soil. This leads to decrease in the compression index of the soil, increase in the shear strength of the soil which ultimately leads to the stability of the soil.

Electro-osmotic consolidation involves the application of electric potential across the soil layers. This would generate a negative pore-water pressure, and after, the flow of pore-water starts from the anode to cathode. So, water moves from anode to cathode from where it can be collected and pumped out of the soil.

The soil is consolidated and the strength properties are improved. It is evident that the improvement of soil properties is permanent. Electro-osmotic flow depends on the properties such as the nature of the soil, water content, pH and on ionic type concentration in the pore-water. Due to the electric potential, the electrolysis of water occurs at the electrodes.

$$2H2O \rightarrow O2\ (g) + 4H+ + 4e-\ \text{oxidation (anode)}$$

It provides uniform pore water movement in most type of soils. This method is effective for local application on small volumes or for impermeable barrier construction. After the Electro-osmotic treatment, the water content decreases and the shear strength increases. Bearing capacity of peaty/mushy soils also can be improved. Thus, the Electro Osmotic Consolidation technique is used for increasing the shear strength of peat soils in a short period of time.

2. Methodology

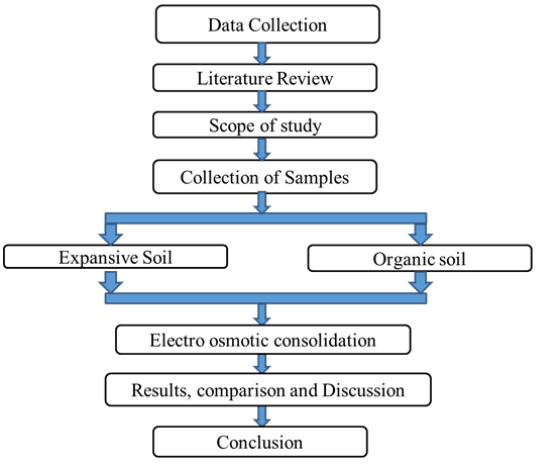

Fig. 1. Methodology

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3. Experimental Setup

A. Objectives

The main objective of the project is,

- To study the effects of electro osmotic consolidation on peat soil from Nadukani, Nilgiris, Tamil Nadu based on the laboratory tests performed on undisturbed specimen.
- To indicate the electro osmotic parameters, soil resistivity and electro osmotic permeability coefficient.
- Electro osmotic consolidation technique can be used in applications including stabilization of slope and increasing the strength of clay.

B. Selection of Location

The region with high elevation experiences major disaster such as landslide, flood and other natural calamities due to heavy downpour. In Tamil Nadu, Nilgiris is one of the regions receiving highest rainfall, where landslides occur abruptly and causes various land destruction. Nadukani, Nilgiris region is known for Landslide prone area. This region comprises of more amounts of peat and marshy soil. Peat soil is the accumulation of decayed, vegetation and organic matter. It also releases CO_2, which helps in maintaining the equilibrium. It has high compression and low shear strength. So, there is a difficulty in consolidation process. In addition to that peat soils generally possess low bearing capacity and hence this soil is not suitable for construction of any structures without any proper soil treatment which is highly economical one.

Fig. 2. Map of Nadugani

Fig. 3. Location of soil sample

C. Electro Osmotic Consolidation Setup

The electro osmotic consolidation setup consists of two electrodes the anode and the cathode. A small electric potential is applied between the layers of soil. A negative pore pressure is generated. The pore water starts to flow from the anode to the cathode, where the water is collected and pumped out of the soil.

The experimental setup is made up of a wooden basin to contain the soil. It has measurement scales to calculate the volume of soil. An outlet is provided to drain out the water. Two Iron rods form the Anode and Cathode respectively. External power supply is provided. A piston along with weight is attached to compress the soil after draining the water.

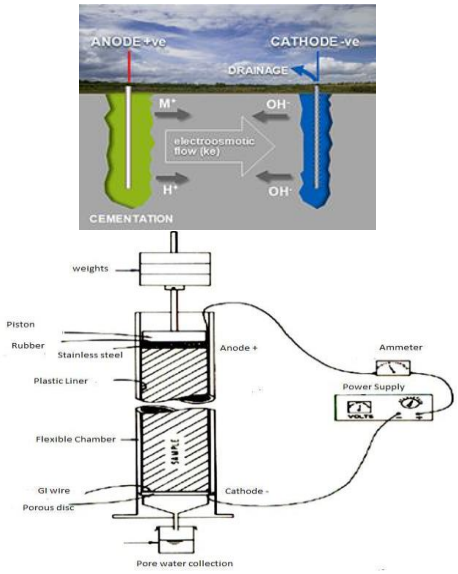

Fig. 4. Experimental setup

D. Tests on virgin properties of the soil

1) Moisture Content Test

The method is based on removing soil moisture by oven-drying a soil sample until the weight remains constant. The moisture content (%) is calculated and evaluated from the sample weight before and after drying. The amount of water is determined by the dry weight and the initial weight, and the moisture content is calculated as the amount of water divided by the total weight, depending on the reporting value.

$$MC = ((W-D)/W) * 100$$

W – wet weight
D – dry weight

2) Specific Gravity Test

Specific gravity is the ratio of the density of a substance to the density of a reference substance; it is also the ratio of the mass of a substance to -the mass of a reference substance for the given volume. This will allow the user to determine if the test sample will be heavier or lighter than the standard fluid.

The specific gravity of the soil particles lies in the range of 2.65 to 2.85. Soils containing organic matter and porous particles have specific gravity values below 2.0. Soils having heavy substances might have values above 3.0.

$$G = \{[(W_2-W_1)(W_3-W_4)]/[W_2-W_1]\}100$$

Fig. 5. Specific gravity test

3) Organic Content Test

The organic content is the ratio of the mass of organic matter in a given mass of soil to the mass of the dry soil.

Organic matter influences many of the physical, chemical and biological properties of soils. It also affects the properties such as the water holding capacity, nutrient contribution, biological activities and water and air infiltration rates.

4) Liquid Limit Test

Liquid limit is the limiting moisture content at which the cohesive soil passes from liquid state to plastic state. LL is efficient to know the stress history and general properties of the soil met with civil works. From the results the compression index may be estimated.

Fig. 6. Liquid limit test

5) Proctor Compaction Test

The Proctor compaction test is a laboratory method of determining the optimal moisture content at when the given soil type will become most dense and achieve its maximum dry density.

$$E = \frac{NnWh}{V}$$

N – Number of blows per layer
N – Number of layers
W – Hammer weight
h – Height of drop
V – Volume of mould

Fig. 7. Proctor compaction test

6) PVane Shear Test

The vane shear test is a method of measuring the undrained shear strength of a cohesive soil sample. The test is executed with equipment consisting of a rod with vanes mounted to it that is inserted into the ground and rotated. A gauge on the top of the apparatus measures the torque required to cause failure of the soil sample and provides a conversion to shear strength.

$$S = \frac{T}{\pi\left(\frac{D^2H}{2} + \frac{D^3}{6}\right)}$$

D - Diameter of vane in cm
H - Height of vane in cm
T – Torque

7) Permeability Test

The rate of flow of water, under the laminar flow conditions, through a unit cross sectional area of soil mass, under the unit hydraulic gradient, is defined as the coefficient of permeability. Permeability of the soil governs the magnitude of excess pore water pressure built-up in the embankment or cuttings, during consolidation process or when the embankment is ponded by water.

$$K = \frac{qL}{Ah}$$

k – coefficient of permeability
q – Discharge in cm^3/s
L – length of specimen in cm
A – cross sectional area of specimen in cm^3
h – constant head causing flow in cm.

4. Results and Discussions

A. Tests on virgin properties of the sample

1) Moisture content test

The moisture content of the soil was determined as per "IS 2720-2 (1973): Methods of test for soils, Part 2: Determination of water content"

The moisture content of the soil sample was found to be 10%.

2) Specific gravity test

The specific gravity of the soil was determined as per "IS 2720: part -3/sec 1-1980, IS 2720: part 3/sec 2:1980. Methods of test for soil: part determination of specific gravity section 1 fine grained soil".

The specific gravity of the soil sample was found to be 1.14.

3) Organic content test

The organic content of the soil was determined as per "IS 2720-1 (1983): Methods of test for soils, Part 1: Preparation of dry soil samples for various tests"

The amount of organic content was found to be 83.33%.

4) Liquid limit test

The liquid limit of the soil was determined as per "IS 2720: part 5:1985 Methods of the test for the soils-part 5: Determination of liquid and plastic limit".

From the figure 8, the liquid limit of the soil is found to be 27.3%

5) Proctor compaction test

The moisture content of the soil was determined as per "IS: 2720(Part 7)-1980- Methods of test for soils: Determination of water content-dry density relation using light compaction."

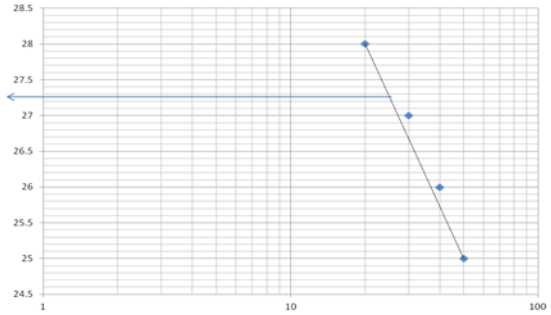

Fig. 8. Graph of liquid limit test

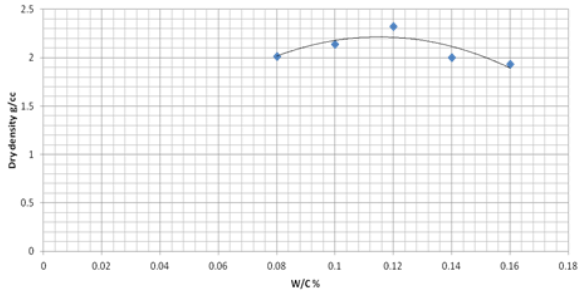

Fig. 9. Graph of proctor compaction test

From the graph,

Optimum Moisture Content = 12%

Maximum Dry Density = 2.2 g/cc

6) Vane shear Test

The shear strength of the soil was determined as per "IS 443 (1978): Code of practice for in-situ vane shear test for soils".

The shear strength was of the soil sample was found to be 0.01 MPa.

7) Permeability test

The permeability of the soil was determined as per "IS 2720 (1986) part 17: Laboratory determination of permeability"

The permeability of the soil sample was found to be $2.65*10^{-6}$ cm/s.

Table 1
Summary on virgin properties of the soil

S. No.	Name of the Test	Results
1	Moisture content test	10%
2	Specific gravity test	1.14
3	Organic content test	83.33%
4	Liquid limit test	27.3%
5	Proctor compaction test	OMC -12% and MDD-2.2g/cc
6	Vane shear test	0.01MPa
7	Permeability test	2.65x10^-6 cm/s

B. Test on soil after electro osmotic consolidation

1) Moisture content test

The moisture content of the soil was determined as per "IS 2720-2 (1973): Methods of test for soils, Part 2: Determination of water content"

The moisture content of the soil sample was found to be 7.48%.

2) Specific gravity test

The specific gravity of the soil was determined as per "IS 2720: part -3/sec 1-1980, IS 2720: part 3/sec 2:1980. Methods of test for soil: part determination of specific gravity section 1 fine grained soil".

The specific gravity of the soil sample was found to be 1.68.

3) Organic content test

The organic content of the soil was determined as per "IS 2720-1 (1983): Methods of test for soils, Part 1: Preparation of dry soil samples for various tests"

The amount of organic content was found to be 83%

4) Liquid limit test

The liquid limit of the soil was determined as per "IS 2720: part 5:1985 Methods of the test for the soils-part 5: Determination of liquid and plastic limit".

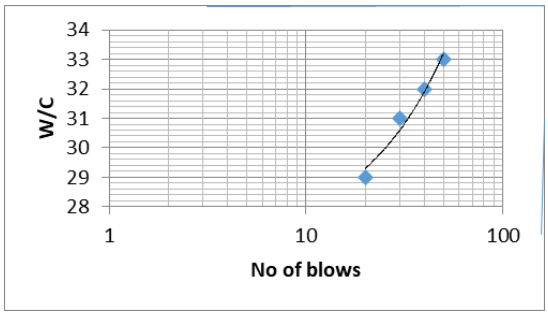

Fig. 10. Graph of liquid limit test

From the graph, the liquid limit of the soil is found to be 30.2%.

5) Proctor compaction test

The moisture content of the soil was determined as per "IS: 2720(Part 7)-1980- Methods of test for soils: Determination of water content-dry density relation using light compaction."

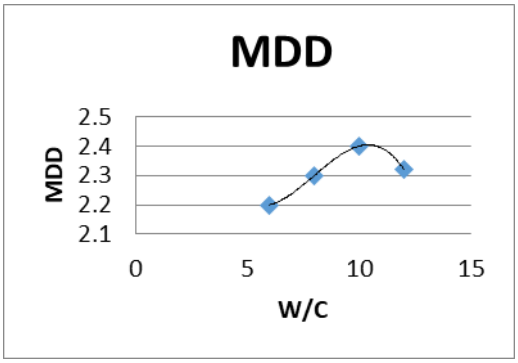

Fig. 11. Graph of proctor compaction test

From the graph,

Optimum Moisture Content = 10%

Maximum Dry Density = 2.4 g/cc

6) Vane shear test

The shear strength of the soil was determined as per "IS 443 (1978): Code of practice for in-situ vane shear test for soils".

The shear strength was of the soil sample was found to be 0.98 MPa.

7) Permeability test

The permeability of the soil was determined as per "IS 2720 (1986) part 17: Laboratory determination of permeability".

The permeability of the soil sample was found to be $3.64*10^{-5}$ cm/s.

Table 2
Summary on properties of the soil after consolidation

S. No.	Name of the test	Results
1	Moisture content test	7.48%
2	Specific gravity test	1.68
3	Organic content test	83%
4	Liquid limit test	30.2%
5	Proctor compaction test	OMC -10% and MDD-2.4g/cc
6	Vane shear test	0.98MPa
7	Permeability test	3.64x10^-5 cm/s

5. Conclusion

The results show the significant potential and scope for improving the soil strength in the hilly regions. The tests done before and after consolidation clearly states that the use of electricity at right amount does not change the organic content of the soil out reduces the water content in the soil which is the key objective of the experiment. The graphite material uses the best output which maximizes the results. Thus the results convey that the method does not induce environmental issues rather reduces the landslides in the mountainous regions.

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