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The Effect of Electrokinetic Stabilization (EKS) on Peat Soil Properties at Parit Botak area, Batu Pahat, Johor, Malaysia

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Abstract

Objectives: To enhance the compaction properties of peat soil, such as shear strength, compressibility, permeability and consistency limit. **Methods/Analysis:** One of the known techniques is by using Electrokinetic Stabilization to enhance the strengthening properties of peat soil. In this method, aluminum used as electrodes with the voltage potential of 110 V was applied on both cathode and anode electrode at the operational period of 3 hours with an applied load of 50 kg. **Findings**: Some parameters of soil, like shear strength (τ), moisture content (W_N), liquid limit (W_L) and compaction have been observed. Results have shown that the magnitude of shear strength at Parit Raja Haji Ali has improved from 8.8 kPa to 74 kPa and MC was decreased from 568.247% to 309.273%, W_L was increased from 136.107% to 191.225%. **Application**: The experimental results suggest the potential of developing electro kinetic treatment technique to stabilize the physical properties of peat is effectively and efficiently.

Keywords: Compaction, Electrokinetic Stabilization, Moisture Content, Peat Soil, Shear Strength, Soil Stabilization

1. Introduction

Peat soil has considered as having more than 75% organic content with the low shear strength of 5 to 20 kPa[1], with a high moisture content of (250% to 985.40%)[2] and high compressibility, which often result in difficulties when construction work is undertaken on the deposit. Peatland is found in all parts of the world covering about 4.5% of the whole world land[3]. Malaysia is 6th country in the world with the highest amount of total peat soil[4]. In general estimation, peat covers some areas in the Peninsular Malaysia, Sarawak and Sabah while Sarawak contributes the largest peatland in Malaysia[5] as shown in Table 1. In addition, 6300 hectares of the peatland is found in Batu Pahat, Pontian and Muar in West Johor state[6].

Peat soil is considered as one of the most challenging soil for the construction projects due to its poor characteristics such as low shear strength, high water content

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and high compressibility. The excessive settlement occurs when buildings are constructed on peat soil and it consequently causes instability problems such as local sinking and long-term settlement even if the moderate load is subjected to it[3]. Many construction projects and coastal high-rise buildings whose basics are frequently supported by peat soils face problems when given physical existence. Likewise, in Malaysia, the construction industry is facing many challenges related to peat soil stabilization and major economic activities and social developments focusing on the coastal area. One of the major problems for the construction industry in Malaysia is the settlement of peat soil foundation for the development of highways and buildings during or after construction when the soil is not properly treated. To ensure the solution of these problems or at least minimizing their overall negative impact on the industry, Electrokinetic Stabilization methods should be applied[7].

Electrokinetic stabilization (EKS) is define, when the electric potential applied to fluid transport in porous media and physicochemical transport of charged particles happened[7]. In environmental practices, this technique uses Direct Current (DC) or a low electric potential difference, which applied to an array of electrodes placed in the soil to eliminate organic, inorganic and contaminated particles from low permeable soils, sludge, slurries, sediments and groundwater[8]. The in-situ studies and some applications encourage other researchers in the understanding of EK phenomena to enhance the compaction properties of weak soil e.g. peat soil for many approaches like improving stability of excavation, slope stability, unstable embankments, backfill strengthening, soil drainage, remediation of salt-affected soils, dewatering of sludge, assisting pile driving, groundwater lowering, treatment of dispersive soils, enhance oil recovery and soil stabilization of fine-grained soils[1].

Table 1. The distribution of peat soil in Malaysia[6]

State	Peatland (ha)	Percentage (%)
Sarawak	1,697,847	69.08
Selangor	164,708	6.70
Pahang	164,113	6.68
Johor	143,974	5.86
Sabah	116,965	4.76
Terengganu	84,693	3.45
Perak	69,597	2.83
Kelantan	9,146	0.37
Negeri Sembilan	6,245	0.25
Federal Territory	381	0.02
Total Peat Land	2,457,669	100

Different researchers have used different techniques to enhance the shear strength of peat soil, while some researchers have used the Electrokinetic Stabilization treatment with different parameters like voltage gradient, operational period, different electrodes as well as different electrolyte solutions which shows more improvement like the researchers[9] conducted a laboratory-based experiment in Indonesia. The clay samples were collected from East Java, Indonesia. Calcium chloride was used as an electrolyte solution while aluminium was used as an electrode with the electric gradient of 13 V for the duration of 12 hours to 3 days, intervalley. The authors concluded that the shear strength was improved up to 56% with the increase in the liquid limit.

The researchers[10] have conducted Electrokinetic Stabilization treatment for the purpose of improving the shear strength of peat soil and the samples were collected from several locations in Malaysia. The sodium silicate, calcium chloride, calcium oxide and aluminium hydroxide were used as the electrolyte. The authors concluded that the shear strength of peat soil was improved from 7.8 kPa up to 33 kPa. The authors[11] has performed a laboratory-based experiment to increase the shear strength of peat soil by using EK. The peat samples were collected from Selangor, Malaysia and graphite were used as an electrode with the electric gradient of 60 V for the operational period of 7 days. The result has shown improvement in the strength of peat soil up to 29 kPa.

The authors[12] have conducted EK laboratory-based method to improve the shear strength and reduce the moisture content of the soft soil. Two graphite were used as electrodes with an applied voltage gradient of 60 V for the operational period of 4 days with an electrolyte solution of calcium and carbonates, which shows the shear strength was improved from 6 kPa to 60 kPa. The researchers[13] have performed a laboratory-based investigation to modify the strength characteristics of soft clay soil by using electrokinetic treatment. The authors have used mild steel as an electrode while applied the electric gradient of 2.0 V/cm for the operational period of 7 to 60 days, which shows the highest improvement of strengthening up to 200%.

2. Materials and Method

In this study, peat soil samples were investigated amongst twenty sites including Parit Haji Ali and Parit Nipah. The

(a) (b)

Figure 1. .(a) In-situ shear strength; (b) Ex-situ shear strength by using field vane shear apparatus.

sampling sites were chosen based on low shear strength (kPa) locating at Parit Botak area, Batu Pahat, Johor Malaysia. Several types of land activities e.g. palm oil and pineapple plantations take place on the sites. Visual identification shows that the peat soil was dark brown in colour, very soft and contains the organic content of more than 95%. Plant structures such as roots and wood were easily recognizable from the peat samples. The peat samples were taken from two different locations, the shear strength was measured with the help of (field vane shear) as shown in Figure 1 (a), at the depth of 20 cm, 30 cm and 40 cm respectively, according to EK cell size. The samples were carefully transferred to the laboratory to avoid any characterization loss. Some physical tests e.g. shear strength, moisture content; liquid limit and compaction test exist for determining the physical properties of peat soil. The ex-situ shear strength was measured in the laboratory as shown in Figure 1 (b).

3. Physical Properties Tests

The physical properties tests were performed for both specimens' pre-EK (untreated peat soil) and post EK (treated peat soil) to observe the physical properties of peat soil. The physical properties include shear strength test, moisture content, liquid limit, maximum dry density and optimum moisture content.

3.1 Shear Strength Test

The in-situ shear strength and ex-situ test were performed by using the field vane shear apparatus. The ex-situ shear strength was measured after electrokinetic treatment, the field vane shear apparatus was put inside a soil specimen in EK cell.

3.2 Moisture Content Test (W_N)

The moisture content was determined according to British standard methods (BS1377: Part 2) by using the oven-drying method. The specimen was put in an inside dry oven for 16 to 24 hours at 105°C to 110°C temperature.

3.3 Liquid Limit Test (W_L)

The liquid limits test was carried out according to the British standard (BS1377: Part 2) by using the cone penetration method. The peat soil was sieved through 424 μm and then air-dried for 16 to 24 hours to achieve maximum moisture content.

3.4 Compaction Test

Standard Proctor compaction test was conducted according to (BS1377-1990: Part 4) to determine the maximum dry density (kg/cm^3) (MDD) and Optimum Moisture Content (OMC) of the peat. In the standard proctor compaction test, the soil was compacted in a mould and the mould was attached to a base plate. The soil was mixed with some amount of water and subsequently compacted in three equal layers using a hammer that deliver 27 blows to each layer, while the hammer energy was 2.5 Kg.

4. Electrokinetic Stabilization (EKS) Treatment

The Electrokinetic Stabilization treatment was carried out in a laboratory-based environment with an ambient temperature of 27°C and the experiment was held at the Research Centre for Soft Soil (RECESS), UTHM. The EKS cell designed for this research was made up of the transparent acrylic plate with rectangle shape open at the top with 40 cm of depth and 42 cm of width whereas the thickness of the acrylic plate was 1.5 cm.

The transparent acrylic plate for EK cell was used to prevent short-circuiting to monitor the soil level during consolidation and the level of water. The EK cell was divided into 3 major parts namely anode, cathode and soil compartment, as shown in Figure 2. The two outside sections were reserved for the anode and cathode while the middle section was reserved for the contaminated soil. The anode and cathode sections were 10 cm while the soil compartment was 17 cm. The electrodes were inserted vertically into the soil specimen with a distance of 10 cm between each electrode. Two aluminium electrodes plates

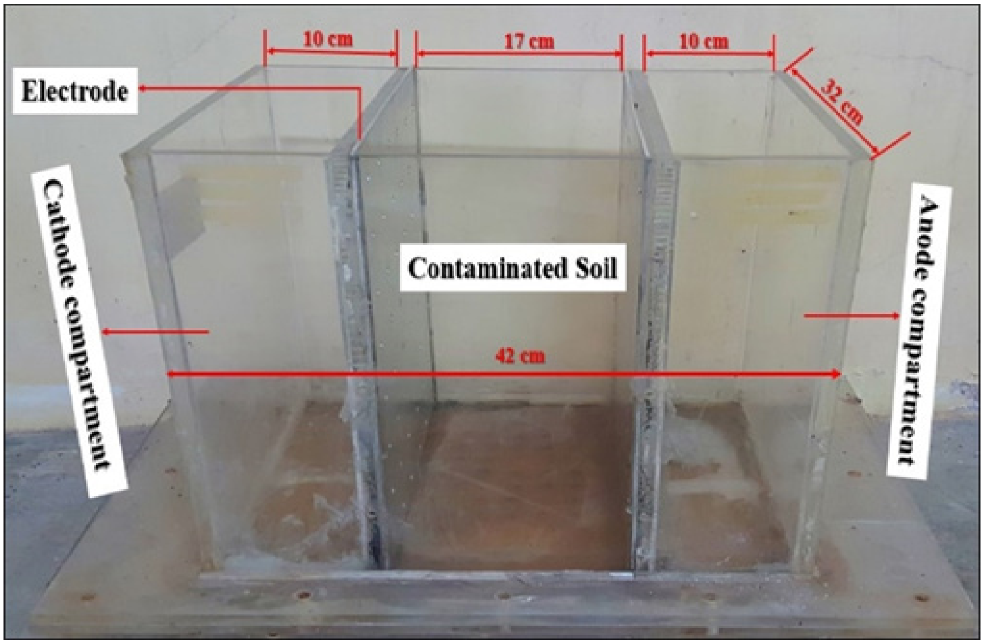

Figure 2. EK stabilization compartments and its dimension.

(a) (b)

Figure 3. (a) EK stabilization treatment with an applied load of 50 kg, (b) A photo of a complete set of Electrokinetic Stabilization treatment with a voltage gradient of 110 V.

were placed in the anode and cathode compartment to pass the Direct Current (DC) into the soil specimens as shown in Figure 2. The load of 50 kg was applied to peat soil as shown in Figure 3 (a), with a voltage gradient of

110 V as shown in Figure 3 (b), for the operational period of 3 hours.

5. Result and Discussion

5.1 Physical Properties of Untreated Peat

The physical properties like shear strength, moisture content, liquid limit and compaction test were performed for untreated peat soil for pre Electrokinetic Stabilization treatment which shows the original properties of peat. The physical properties for untreated peat soil are tabulated in Table 2.

5.2 Shear Strength for Untreated Peat Soil

The shear strength was measured during the sampling period by using the field vane shear apparatus. The initial result shows that shear strength for Parit Haji Ali was 8.8 kPa, while shear strength was observed 9.9 kPa for Parit Nipah.

5.3 Moisture Content Test for Untreated Peat Soil

The initial result shows the moisture content for Parit Haji Ali untreated peat was 476.849%, while Parit Nipah untreated peat soil was observed 502.594% as tabulated in Table 2.

5.4 Liquid Limit Test for Untreated Peat Soil

The liquid limit test was done in the laboratory according to the British standard (BS 1377: Part 2), which shows that liquid limit was 136.107% for Parit Haji Ali, while for Parit Nipah the liquid limit was observed 182.534%.

5.5 Compaction Test for Untreated Peat Soil

The standard Proctor compaction test was done for both samples. The initial results show that maximum dry density (kg/cm^3) MDD was observed 6.97×10^{-7} kg/m^{3}and optimum moisture content OMC was 48.812% for Parit Haji Ali, while MDD was observed up to 6.90×10^{-7} kg/m^3 and OMC was 46.66% for Parit Nipah.

6. Physical Properties of Treated Peat (with a load of 50 kg)

The post EK with an applied load of 50 kg show different properties where the shear strength and liquid

Table 2. The physical properties of untreated peat soil at Parit Botak area

Properties	Parit Haji Ali	Parit Nipah	References	
Shear Strength (KPa)	8.8	9.9	3-17	14
OC (%)	97.60	97.88	96.64	1
MC (%)	476.849	502.594	200-700	15
Liquid Limit LL (%)	136.107	182.534	173.75	14
MDD kg/m^3	6.97×10^{-7}	6.90×10^{-7}	(490-850) (112-800)	14

limit was increased while the moisture content was decreased as compared to pre EK (untreated soil). The load of 50 kg was applied before EK treatment. After removing the load form EK cell, the peat soil was observed compacted with low moisture content and compressibility.

6.1 Shear Strength (kPa) of Treated Peat

The shear strength of peat was improved with an applied voltage gradient of 110 V for the operational period of 3 hours with a load of 50 kg. The results show that shear strength was improved up to 74 kPa for Parit Haji Ali while it was increased up to 68 kPa for Parit Nipah peat soil.

6.2 The Moisture Content of Treated Peat

The moisture content was reduced to be reduced with an applied load of 50 kg along with the voltage gradient of 110 V for the operational period of 3 hours. The moisture content was observed 309.273%. Similarly, for Parit Nipah, it was observed 284.72%.

6.3 Liquid Limit (W_L) of Treated Peat

The liquid limit was observed to be increased with an applied load of 50 kg along with a voltage gradient of 110 V for the operational period of 3 hours respectively. The liquid limit for Parit Haji Ali was 191.225%,

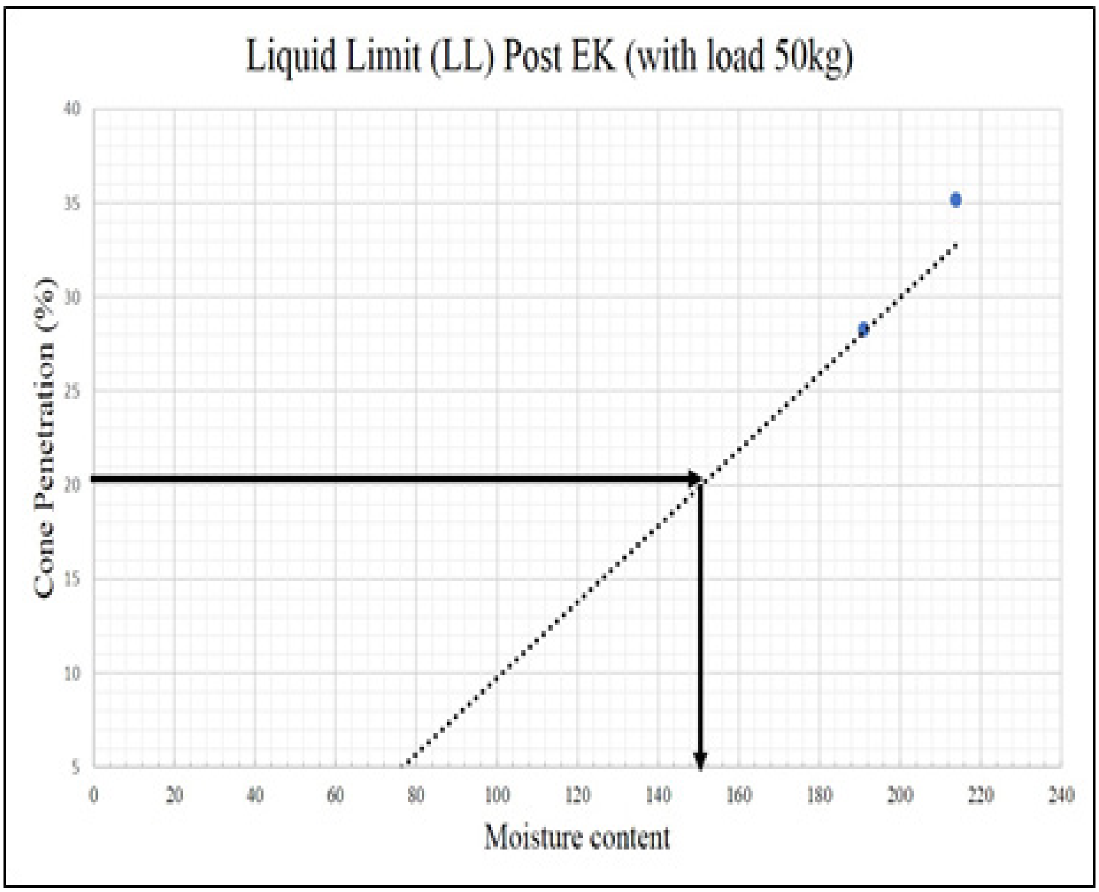

Figure 4. Liquid Limit (LL) result for post EK.

while it was observed 214.860% for Parit Nipah peat soil.

6.4 Compaction Behavior of Treated Peat

The maximum dry density (kg/cm^3) and optimum moisture content were observed increased with applied load of 50 kg along with voltage gradient of 110 V for the operational period of 3 hours. The Parit Haji Ali sample shows that MDD was increased up to 8.52 × 10^{-7} kg/m^3 while OMC was increased to 127.649%. Similarly, for Parit Nipah the MDD was increased up to 8.42 × 10-7 kg/m^3 while OMC was improved up to 140.303% as shown in Figures 4 and 5.

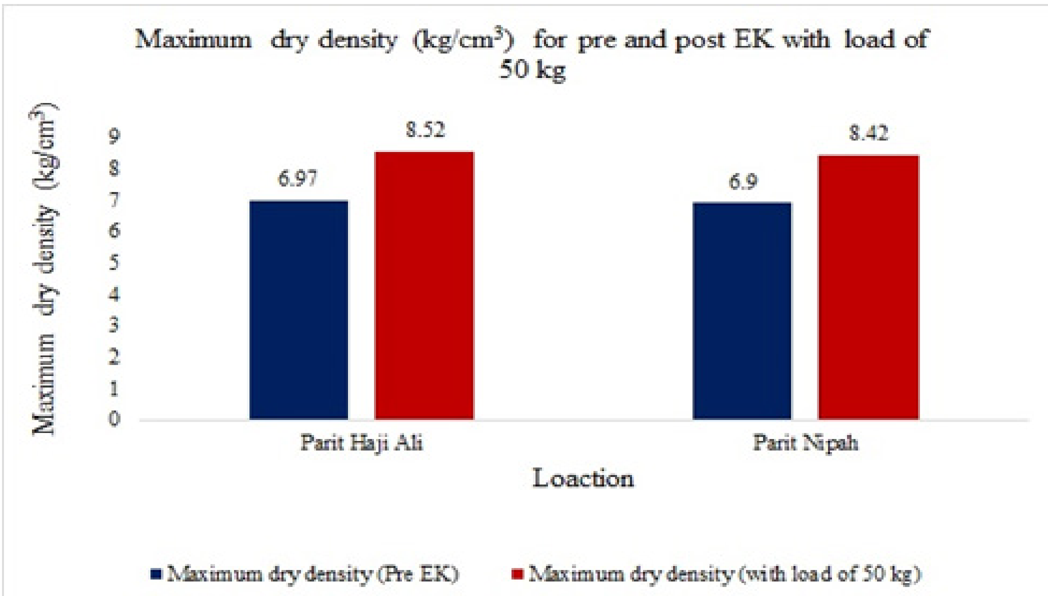

Figure 5. Maximum dry density comparison for pre and post EK.

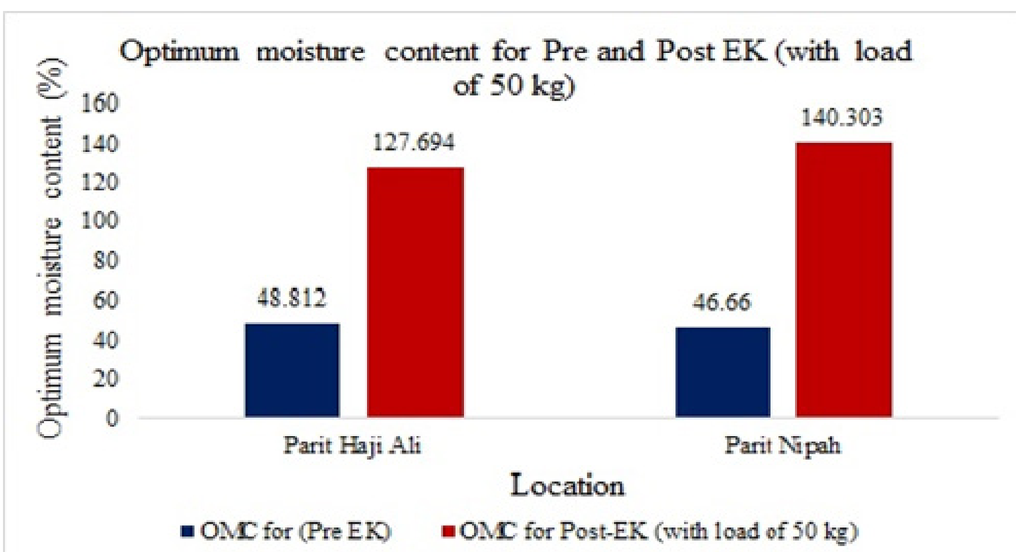

Figure 6. Optimum moisture content comparison for pre and post EK.

7. Comparison between pre-EK and post-EK

The physical properties were observed to have different values in Pre and Post EK when the load of 50 kg was applied to the specimens; the shear strength and the liquid limit were increased, while moisture content and compressibility was reduced. In Figure 6 this section, the comparison of untreated peat soil (pre-EK) with treated peat soil (post-EK) explained in detail.

7.1 Shear Strength Pre and Post-EK

The shear strength for Parit Haji Ali untreated peat was 8.8 kPa, and Parit Nipah shear strength was 9.9 kPa, while after applying the load of 50 kg along with voltage gradient of 110 V for the operational period of 3 hours, the shear strength was improved to 74 kPa for Parit Haji Ali and 68 kPa for Parit Nipah as shown in Figure 7.

7.2 Moisture Content Pre and Post-EK

The moisture content was observed reduced with an applied load of 50 kg along with a voltage gradient of 110 V for the operational period of 3 hours. Figure 8 shows Parit Haji Ali, moisture content was reduced from 568.247% to 309.273%. Similarly, for Parit Nipah, the moisture content was reduced from 502.594% to 284.72%.

7.3 Liquid Limit (LL) Pre and Post-EK

The liquid limit was improved as compared to pre EK with an applied load of 50 kg along with a voltage gradient of 110 V for the operational period of 3 hours as shown in Figure 9. The LL for Parit Haji Ali was observed 136.107%, while after treatment it was observed to be improved to 191.225%. Similarly, for Parit Nipah it was observed from 182.534% to 214.860%.

7.4 Compaction Test for Pre and Post EK

The maximum dry density (kg/cm^3) (MDD) and Optimum Moisture Content (OMC) was increased and with applied load of 50 kg with voltage gradient of 110 V for the operational period of 3 hours.

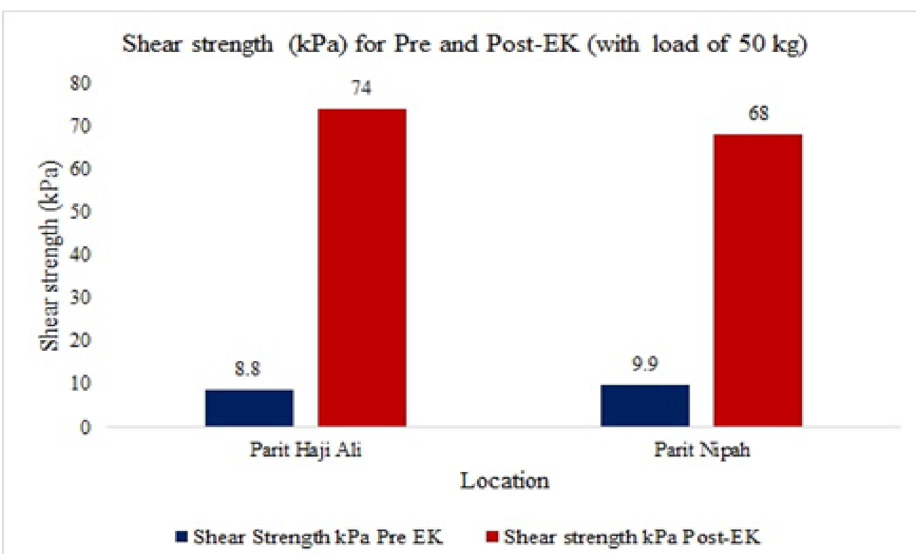

Figure 7. Shear strength (kPa) comparison between pre and post EK.

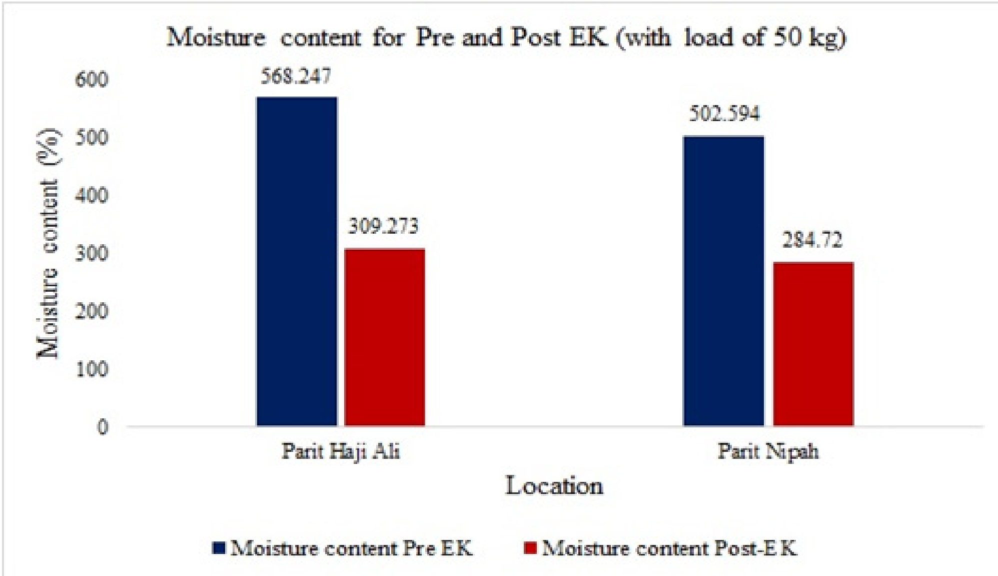

Figure 8. Moisture content comparison between pre and post EK.

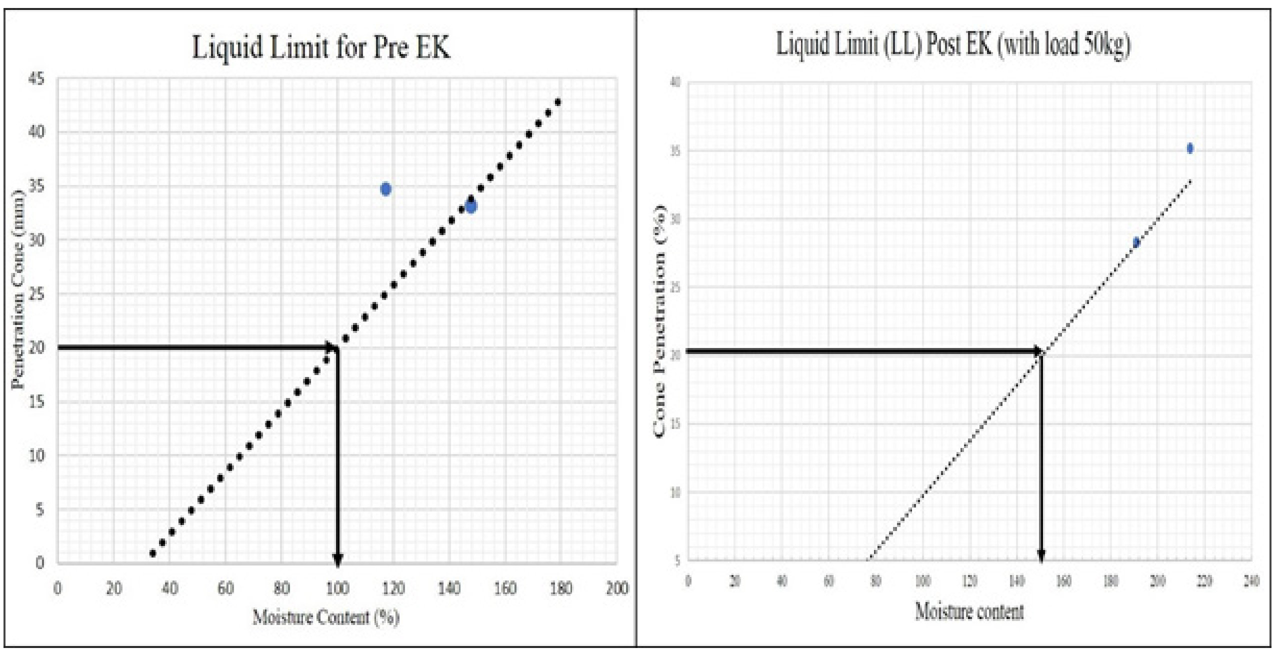

Figure 9. Liquid limit comparison for pre and post EK.

7.5 Maximum Dry Density for Pre and Post EK

The treated peat soil with Electrokinetic Stabilization method shows, the MDD was increased from 6.97×10^{-7} kg/m^3 to 8.52×10^{-7} kg/m^3 for Parit Haji Ali while MDD for Parit Nipah was increased from 6.90×10^{-7} kg/m^3 8.42×10^{-7} kg/m^3 with applied load of 50 kg along with voltage gradient of 110 V for the operational period of 3 hours as shown in Figure 4.

7.6 Optimum Moisture Content (OMC) Pre and Post-EK

The optimum moisture content was improved when voltage gradient of 110 V with a load of 50 kg was applied for an operational period of 3 hours whereas the OMC was increased from 48.812 % to 127.694 % for Parit Haji Ali while OMC was improved from 46.66 % to 140.303% as shown in Figure 5.

8. Conclusion

The following conclusions were drawn after performing EKS treatment on peat soil of the Parit Botak area.

The shear strength (kPa) was observed to have maximum from 8.8 kPa up to 74 kPa for Parit Haji Ali, whereas for Parit Nipah, the shear strength was improved from 9.9 kPa to 68 kPa.

The moisture content results show, that moisture content was reduced when applying a load of 50 kg with a voltage gradient of 110 V. The moisture content for Parit Haji Ali was reduced from 568.247% to 309.273% and it was reduced from 502.594% to 284.72% for Parit Nipah.

The liquid limit was improved when applying a load of 50 kg with a voltage gradient of 110 V for an operational period of 3 hours, the liquid for Parit Haji Ali was increased from 136.107% to 191.225% while, it was improved from 182.534% to 214.860% for Parit Nipah.

The maximum dry density (kg/cm^3) was increased when applying load of 50 kg along with voltage gradient of 110 V for the operational period of 3 hours, where the maximum dry density was increased from 6.97×10^{-7} to 8.52×10-^{7} kg/m^3 for Parit Haji Ali, while it was improved from 6.90×10^{-7} to 8.42×10^{-7} kg/m^3 for Parit Nipah.

The optimum moisture content OMC was observed to be increased when applying a load of 50 kg along with a voltage gradient of 110 V for the operational period of 3 hours. Parit Haji Ali result shows that OMC was increased from 48.812% up to 127.694%, while it was increased from 46.665 to 140.303% for Parit Nipah.

The changes in shear strength and moisture content parameter of each sampling site between pre and post-EKRS indicate that shear strength is inverse proportional to moisture content.

9. Future Recommendation

The Electrokinetic Stabilization method shows outstanding performance with an applied load of 50 kg along with a voltage gradient of 110 V for the operational period of 3 hours. Hence if the load and voltage gradient will be increased as well as the operational period, it may easily enhance the physiacal properties of soft soil at very less cost.

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