*Bulletin of the Geological Society of Malaysia, Volume 70, November 2020, pp. 133 - 138*
DOI: https://doi.org/10.7186/bgsm70202011

# Peat soil engineering and mechanical properties improvement under the effect of EKS technique at Parit Kuari, Batu Pahat, Johor, West Malaysia

Abdul Wahab[1,2,*], Zaidi Embong[1,2], Muzamir Hasan[3], Habib Musa[4], Qamar UZ Zaman[5], Hidyat Ullah[6]

[1]Research Centre for Soft Soil (RECESS), Universiti Tun Hussein Onn Malaysia, Johor, Malaysia
[2]Faculty of Applied Science and Technology (FAST), Universiti Tun Hussein Onn, Malaysia, Johor, Malaysia
[3]College of Engineering, Universiti Malaysia Pahang, Malaysia
[4]Faculty of Engineering, Universiti Malaysia Sabah, Malaysia
[5]Department of Geology, Northwest University, Xian, PR China
[6]Department of Science and Technology, University of Stavanger, Norway
* Corresponding author email address: wahab.dir555@gmail.com

**Abstract:** This study focused on the stabilization of peat soil and its engineering and mechanical properties improvement such as shear strength, moisture content, liquid limit and shear wave velocity. Peat is considered as weak foundation soil as they have low shear strength, high compressibility and high moisture content. One of the major problems for the construction industries in Malaysia is slope instability, bearing capacity failure and excessive settlement foundation for the development of highways and buildings when its undertaken-on peatland. Malaysia contains about 3 million hectares peatland which cover 8% of its total land. Therefore, it is essential to find an appropriate way to enhance its properties and to ensure the reduction and solution of these problems can finally solve by applying the electrokinetic stabilization (EKS) method. The peat soil samples were collected from Parit Kuari, Batu Pahat, Johor, Malaysia. In the proposed technique, the voltage gradient of 110 and 150 V was applied for the period of 3 and 6 hours. Some laboratory parameters such as shear strength, moisture content (MC), liquid limit, and shear wave velocity were observed for pre as well as for post-EK. It was observed that strength was found significantly improved from 11.66 to 70 kPa, MC was reduced from 613.989 to 270.294%, liquid limit was increased from 159.261 to 217.603%, and shear wave velocity was improved from 68.5 to 110.5 m/s. A significant improvement has been observed in the physical properties of the peat soil by applying the progressive approach showing the robustness of the methodology.

**Keywords:** Peat soil, shear strength, electrokinetic stabilization

## INTRODUCTION

Peatland is found in all parts of the world, especially in tropical countries which covered about 4.5% of the whole world land (Abdel-Salam, 2017), as tabulated in Table 1. Malaysia is the 9$^{th}$ country in the world with the highest quantity of total peat soil (Mohamad, 2015). In overall, estimation of peat-land covers some areas in Peninsular Malaysia, Sarawak, and Sabah, however Sarawak state has the largest peat-land in Malaysia as tabulated in Table 2 (Moayedi & Nazir, 2018).

. In addition, 6,300 hectares of the peatland is found in Batu Pahat, Pontian, and Muar in West Johor state (Melling, 2016). Peat soils are considered as a challenging soil with having more than 75% organic contents, low shear strength (5 to 20 kPa), high moisture content (250% to 985.40%) and high compressibility, which often results in difficulties when construction work is undertaken over it (Razali *et al*., 2013).

The construction on peat soil is considered as one of the challenging tasks for the construction engineers, due to its poor characteristics. Problems such as slope instability, bearing capacity failure and excessive settlement occurs when moderate load is subjected on it, which causes instability problem such as local sinking or long-term settlement during or after the construction of buildings or roads (Abdel-Salam, 2017). In Malaysia, one of the major challenges that construction industries are facing is the settlement of peat soil foundation for development of buildings and highways when it's 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 to the soft soil for its properties improvement e.g., shear strength (Hua *et al.,* 2016).

Previously some researchers examined EK method for the improvement of low permeable soil such as Thuy *et al*. (2013) who conducted laboratory based electrokinetic stabilization experiment to improve and strengthen the physical properties of clay soil. The clay samples were collected from East Java, Indonesia. Calcium chloride was used as an electrolyte solution and aluminum was practiced

**Table 1:** Peatlands worldwide distributions (Mesri & Ajlouni, 2007).

| Country | Peatland (km$^2$) | (%) of land area |
|---|---|---|
| Canada | 1,500,000 | 18 |
| U.S.S. R | 1,500,000 | |
| United States | 600,000 | 10 |
| Indonesia | 170,000 | 14 |
| Finland | 100,000 | 34 |
| Sweden | 70,000 | 20 |
| China | 42,000 | |
| Norway | 30,000 | 10 |
| Malaysia | 25,000 | 8 |
| Germany | 16,000 | |
| Brazil | 15,000 | |
| Ireland | 14,000 | 17 |
| Uganda | 14,000 | |
| Poland | 13,000 | |
| Falklands | 12,000 | |
| Chile | 11,000 | |
| Zambia | 11,000 | |
| 26 other countries | 220 to 10,000 | |

Sources: (Colley, 1950; Taylor, 1983; Ng & Eischens, 1983; Moore, 1989; Hansbo, 1991)

**Table 2:** Peatland distribution in Malaysia (Melling, 2016).

| 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 |

as an electrode with electric gradient of 13 V for the periods of 12 hours to 3 days.

The authors stated that the shear strength was improved up to 56% while the liquid limit was increased.

Keykha *et al*. (2014) observed a laboratory based electrokinetic experiment with the aim to enhance the engineering properties of soft soil such as shear strength and moisture content.

They applied the voltage gradient of 60 V for the duration of 4 days with the help of two graphite laminate electrodes with calcium carbonate electrolyte solution. Their results showed the shear strength was improved from 6 to 60 kPa.

Wahab *et al*. (2018) conducted the electrokinetic laboratory-based experiment to strengthen the engineering properties of peat soil. The samples were collected from Parit Botak area, Batu Pahat, Johor, Malaysia. The voltage gradient of 110 V was applied through aluminum electrode with the subjected load of 50 kg for the duration of 1 to 3 hours. Their results revealed that shear strength was improved from 8.8 kPa to 75 kPa and 9.9 kPa to 69 kPa for different peat specimens while the moisture content was reduced from 568.248 % to 309.274% and 502.595% to 284.73% in different phases.

Hosseini *et al.* (2019) performed EK experiment to improve the shear strength of collapse soil. The soil sample was collected from Golestan province, Iran. The electric voltage of 30 V was applied through copper and steel electrodes for a period of 2 days and lime was used as electrolyte solution. Their results stated that shear strength was increased from 50 to 400 kPa (about 30%) with different voltage and duration.

Kherad *et al*. (2020) studied the evaluation of electrokinetic technique to strengthen the mechanical and chemical characteristic of expansive soil. They applied different voltage gradients of 0.46 V/cm, 0.92 V/cm, and 1.84 V/cm for a time period of 1, 2, 7 and 28 days. The authors stated that around anode about 83% reduction was recorded and swell potential was achieved with improved shear strength value up to 800%.

Estabragh *et al*. (2020) observed EK method with the aim to enhance the properties of clay soil. The voltage of 50 V was operated through stainless steel electrode for the duration of 10 days. Calcium chloride and distilled water was used as an electrolyte solution. The authors' results showed that the shear strength was improved 5 times where it was increased from 8.2 kPa to 43 kPa with different duration of operation.

## Soil groups in Johor state

The soil groups in the Johor state are as follows:

### Fluvisols group

This group consists of flood plains and alluvial soils. There are two types of fluvisols, which are Dystric Fluvisols and Thionic Fluvisols, while the local names are Rusila and Kranji. This soil group is generally found on the coastal plain, mostly in tidal swamps covered by mangrove.

### Gleysols group

This group is considered as mucky soils due to excess of water. It is characterized as Dystric gleysols and the local name is Lunas. These groups are mostly found along the Johor river.

### Nitosols group

The Nitosols is a soil group with outlook of shiny pad, namely Dystrie Nitosols and Rhodie Nitosols while the local name is Renggam and Kulai, and is the most abundant soil type in Kota Tinggi district, Johor state.

### Histosols group

This group of soils are structured and are derived from weathering in situ and only one type is found, known as Dystric Histosols, and the common name is peat. It is deposited mostly in swampy area and not far from the coasts of the eastern and southern parts of Kota Tinggi district, Johor state (Saleh *et al*., 2015).

### Ferrasols group

This is a soil with high content of sesquioxides. There are three types found in the north and in the middle parts of Kota Tinggi district. These soil types are characterised as Xanthic Ferrasols, Orthic Ferrasols and Plinthinc Ferrasols. It is also called Holyrood, Munchong and Malacca locally (Saleh *et al*., 2015).

### Acrisols group

This is an acidic soil of low base saturation. Three types are found in the northern, eastern and southern parts of Kota Tinggi district. They are characterised as Ferric Acrisols, Orthic Acrisols and Plinthinc Acrisols, and the local names are Harimau Tampoi or Durian series, Batu Anam and Apek respectively.

### Podzols group

This is a group of Beach Ridge Interspersed with Swales (BRIS) soils. It is characterized as Humic Podzols and the local name is Rudua.

### Miscellaneous soils

These Steep Land and Urban Land soil types are mostly found in the western and northern parts of Kota Tinggi district. Most of Kota Tinggi district is steep land with a forested area above 30 m in height (Yaacob & Jusop, 1982).

## MATERIAL AND METHOD

In this study, the peat sample was collected amongst twenty different sites based on low shear strength, which is Parit Kuari located at Parit Botak area Batu Pahat, Johor Malaysia as shown in Figure 1. The shear strength was measured with the help of field vane shear at the depth of 20 cm, 30 cm and 40 cm, respectively, according to EK cell size as shown in Figure 2.

## ORIGINAL PROPERTIES OF UNTREATED PEAT SOIL (PRE EK)

The physical and mechanical properties were observed for both untreated and treated peat soil where the physical parameters including shear strength, moisture content and liquid limit and mechanical properties such as shear wave velocity were examined as tabulated in Table 3.

**Figure 1:** The sampling location sites.


**Figure 2:** In-situ measurement of shear strength by using field vane shear apparatus.

## ELECTROKINETIC STABILIZATION (EKS) TREATMENT

The EK experiments were carried out at the Research Center for Soft Soil (RECESS), UTHM, in a laboratory environment with ambient temperature of 24 °C to 28 °C. The EKS cell was designed for this research and is made of transparent acrylic plate. The rectangle shaped box is open at the top with 40 cm depth and 42 cm width while the thickness of the acrylic plate is

**Table 3:** The physical and mechanical properties of untreated peat soil

| Physical properties | Parit Kuari | Reference | |
|---|---|---|---|
| Shear strength (kPa) | 11.66 | 3 -17 | Moayedi & Nazir, 2018 |
| Organic Content (%) | 96.248 | 96.64 - 98 | Zainorabidin & Mohamad, 2017 |
| Moisture Content ($W_N$) (%) | 613.989 | 200 - 700 | Zainorabidin & Zolkefle, 2014 |
| Liquid limit ($W_L$) (%) | 159.261 | 130 - 173.75 | Deboucha *et al*., 2008 |
| Shear wave velocity (m/s) | 68.5 | 26.02 - 75.5 | Deboucha *et al*., 2008<br>Wahab *et al*., 2020 |

1.5 cm. The transparent acrylic plate was used with the purpose to prevent short circuiting, and monitoring the soil and water level during consolidation.

The EK cell was divided into 3 major parts such as anode, cathode and soil compartments, as shown in Figure 3. The two outside sections were reserved for the anode and cathode while the middle section was reserved for the soil specimen. The anode and cathode sections were 10 cm while contaminated soil compartment was 17 cm. The electrodes were inserted vertically into the soil specimen with 10 cm distance from each electrode. Aluminum was used as an electrode to permit the direct current (DC) placed in the anode and the cathode compartment where the two passive electrodes were placed at the extreme edges of the soil specimen. The EKS experiment was divided into two phases, in phase I, the voltage of 150 V was applied for the duration of 6 hours while in phase II, the voltage of 110 V was applied with subjected load of 50 kg for the duration of 3 hours.


**Figure 3:** The EK cell for peat soil stabilization.

**Table 4**: The physical and mechanical properties of stabilized peat soil (phase I).

| Parameters | Parit Kuari Peat soil |
|---|---|
| Shear strength (kPa) | 58 |
| Moisture content (%) | 360.213 |
| Liquid limit (%) | 194.408 |
| Shear wave velocity m/s | 92.5 |

## RESULT AND DISCUSSION

### Physical and mechanical properties of treated peat soil

The physical and mechanical properties for treated peat were observed after operating the voltage gradient of 110 V with the subjected load of 50 kg for the duration of 3 hours and 150 V for the period of 6 hours without any subjected load. It was observed that the properties of peat were improved with the voltage and subjected load as tabulated in Table 4.

#### Shear strength of treated soil

The shear strength was measured followed by field vane shear apparatus, after treated the soil with the voltage gradient of 150 V for the operational period of 6 hours. The field vane shear was put inside the soil specimen in EK cell in various positions. The shear strength was improved from 11.66 kPa to 58 kPa in phase I, and it was increased up to 70 kPa in phase II as can be seen in Figure 4.

#### Moisture content of treated soil

The moisture content was observed to be reduced in both phases due to the ion's movement towards electrodes. The moisture content was 360.213 % with the applied voltage of 150 V for the duration of 6 hours in phase I, while it was reduced till 270.6 % when the voltage gradient of 110 V was applied with subjected load of 50 kg for the operational period of 3 hours.

#### Liquid limit (LL) of treated soil

The liquid limit for untreated and treated peat was observed improved with diverse electric voltage where in phase I, it was increased from 159.261% to 194.408% while it was improved up to 217.603 % in phase II.

#### Shear wave velocity of treated soil

The mechanical properties such as shear wave velocity was observed increased in both phases. In phase I, the shear wave velocity was increased from 68.5 m/s to 92.5 m/s while it was increased up to 110.5 m/s in phase II, when the voltage of 110 V was applied with subjected load of 50 kg for the duration of 3 hours repeatedly. It was examined that the soil particles were come closed to each other where the waves cannot move easily due to the high compactness of soil particles.

## COMPARATIVE ANALYSIS BETWEEN TREATED AND UNTREATED PEAT PROPERTIES

As mentioned, above the method was divided into two phases wherein phase I, the voltage of 150 V was applied for the period of 6 hours with the help of aluminum electrode while in phase II, the load of 50 kg was applied before the voltage of 110 V for the operational period of 3 hours through the aluminum electrode. High improvement was observed in phase II, as compared to phase I. The peat soil properties were improved further when the load of 50 kg was applied to peat specimen as in Figures 4, 5 and Table 5.

## CONCLUSION

The following conclusions were attained for untreated and treated peat soil properties by operating different voltage gradients.

- The shear strengths of the peat soil samples were improved after the treatment by using EKS method and providing the voltage gradient of 110 and 150 V for the operational period of 6 hours. The shear strength was increased from 11.66 kPa to 58 kPa and 70 kPa.
- The moisture content results show that water content was reduced in both phases. It was observed to reduce from 613.898% to 360.213% in phase I and 270.294% in phase II.
- The shear wave velocity was also improved in both phases, wherein phase I, it was increased from 68.5 m/s to 92.5 while 110.5 in phase II.
- The changes of shear strength and moisture content parameter from each sampling sites between pre and post EKS indicates that shear strength is inverse proportional to moisture content.

## FUTURE RECOMMENDATION

The EKS method illustrated higher improvement with current practiced parameters. It is highly recommended to apply EKS method for soft soil improvement. The engineering and mechanical properties will be improved further if the high voltage gradient is practiced with excessive load for longer operational period can give an excellent result.


## ACKNOWLEDGEMENT

The authors would like to express their gratitude to Research Centre for Soft Soil (RECESS) that provides all the facilities to ensure the success of this research and appreciation also goes to those friends who had assisted directly or indirectly for the success of this work.


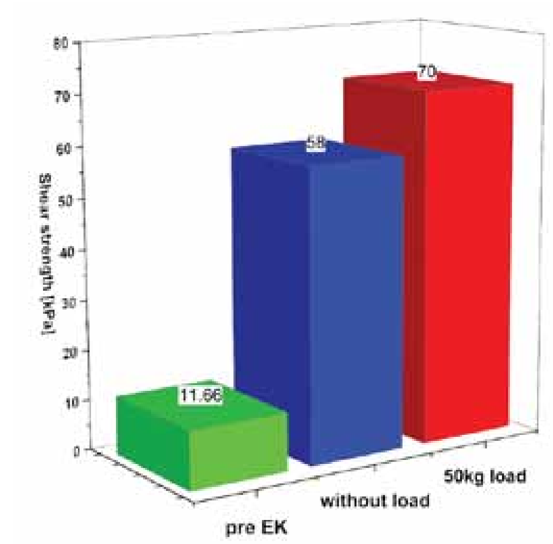


**Figure 4:** Shear strength comparison between untreated and treated peat soil.

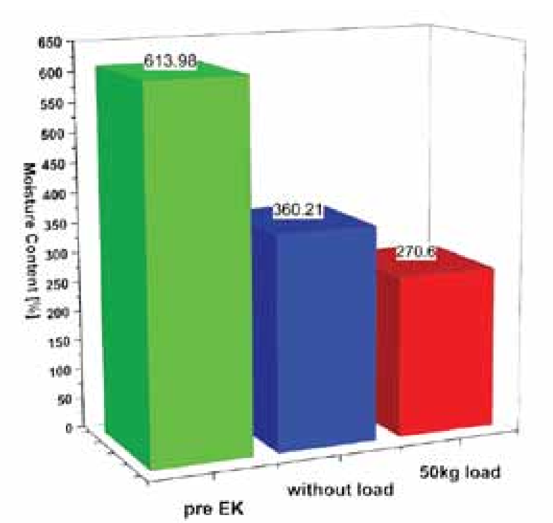


**Figure 5:** Moisture content comparison between untreated and treated peat soil.

**Table 5:** Comparative analysis between treated and untreated properties of peat soil.

| Parameters | Parit Kuari Peat soil | | |
|---|---|---|---|
| | Pre EK (Original properties) | Phase I | Phase II |
| Shear strength (kPa) | 11.66 | 58 | 70 |
| Moisture content (%) | 613.819 | 360.213 | 270.294 |
| Liquid limit (%) | 159.261 | 194.408 | 217.603 |
| Shear wave velocity m/s | 68.5 | 92.5 | 110.5 |

## REFERENCES

Abdel-Salam, A.E., 2017. Stabilization of peat soil using locally admixture. HBRC Journal, 14(3), 294-299.

Colley, B., 1950. Construction of highways over peat and muck areas. American Highways, 29(1), 3-6.

Deboucha, S., R. Hashim, & A. Alwi, 2008. Engineering properties of stabilized tropical peat soils. Electronic Journal of Geotechnical Engineering, 13, 1-9.

Estabragh, A., Moghadas, M., Javadi, A., & Abdollahi, J., 2020. Stabilisation of a clay soil by ion injection using an electrical field. Proceedings of the Institution of Civil Engineers-Ground Improvement, 1-29.

Hansbo, S., 1991. Full-Scale Investigations of The Effect of Vertical Drains on The Consolidation of a Peat Deposit Overlying Clay. De Mello Volume; A Tribute to Professor Dr. Victor Fb De Mello In Honor of His Contribution to The Development of Geotechnical Engineering in Latin America. Editora Edgard Bluecher Ltd., Sao Paulo, Brazil. 176 p.

Hosseini, A., Haeri, S. M., Mahvelati, S., & Fathi, A., 2019. Feasibility of using electrokinetics and nanomaterials to stabilize and improve collapsible soils. Journal of Rock Mechanics and Geotechnical Engineering, 11(5), 1055-1065.

Hua, L. J., Mohd, S., Tajudin, S. A. A., Mohamad, S. N. A., Bakar, I., Masirin, M. I. M. & Mahmood, A. A.-W., 2016. Construction of infrastructure on peat: Case studies and lessons learned. Paper presented at the MATEC Web of Conferences.

Keykha, H.A., B.B. Huat & A. Asadi, 2014. Electrokinetic stabilization of soft soil using carbonate-producing bacteria. Geotechnical and Geological Engineering, 32(4), 739-747.

Kherad, M. K., Vakili, A. H., bin Selamat, M. R., Salimi, M., Farhadi, M. S., & Dezh, M., 2020. An experimental evaluation of electroosmosis treatment effect on the mechanical and chemical behavior of expansive soils. Arabian Journal of Geosciences, 13(6), 1-12.

Melling, L., 2016. Peatland in Malaysia. In: Mitsuru Osaki and Nobuyuki Tsuji (Eds.), Tropical Peatland Ecosystems. Springer, Tokyo, Japan, p. 59-73.

Mesri, G. & M. Ajlouni, 2007. Engineering properties of fibrous peats. Journal of Geotechnical and Geo Environmental Engineering, 133(7), 850-866.

Moayedi, H. & R. Nazir, 2018. Malaysian Experiences of Peat Stabilization, State of the Art. Geotechnical and Geological Engineering, 36, 1-11.

Mohamad, H. M., 2015. Post cyclic behaviour of Malaysian peat soil. Doctoral dissertation, Universiti Tun Hussein Onn Malaysia.

Moore, P.D., 1989. The ecology of peat-forming processes: a review. International Journal of Coal Geology, 12(1-4), 89-103.

Ng, S.Y. & G.R. Eischens, 1983. Repeated short-term consolidation of peats. In: P.M. Jarret (Ed.), Testing of Peats and Organic Soils. ASTM Special Technical Publication 820, Michigan. 240 p.

Ramli, A. T., Rahman, A. T. A. & Lee, M., 2003. Statistical prediction of terrestrial gamma radiation dose rate based on geological features and soil types in Kota Tinggi district, Malaysia. Applied Radiation and Isotopes, 59(5-6), 393-405.

Razali, S.N.M., I. Bakar, & A. Zainorabidin, 2013. Behavior of peat soil in instrumented physical model studies. Procedia Engineering, 53, 145-155.

Saleh, M. A., Ahmad Termizi Ramli, Khaidzir bin Hamzah, Yasser Alajerami, Mohammed Moharib & Ismael Saeed, 2015. Prediction of terrestrial gamma dose rate based on geological formations and soil types in the Johor State, Malaysia. Journal of Environmental Radioactivity, 148, 111-122.

Taylor, J. A., 1983. Peatlands of Great Britain and Ireland. Ecosystems of the World, AGRIS, 4b, 1-46.

Thuy, T. T. T., Putra, D. P. E., Budianta, W., & Hazarika, H., 2013. Improvement of expansive soil by electro-kinetic method. Journal of Applied Geology, 5(1), 50-59.

Wahab, A., Embong, Z., Naseem, A. A., Madun, A., Zainorabidin, A., & Kumar, V., 2018. The Effect of Electrokinetic Stabilization (EKS) on Peat Soil Properties at Parit Botak area, Batu Pahat, Johor, Malaysia. Indian Journal of Science and Technology, 11(44), 1-12.

Yaacob, O. & Jusop, S., 1982. Sains Tanah. Dewan Bahasa and Pustaka, Kuala Lumpur.

Zainorabidin, A. & H.M. Mohamad, 2017. Engineering properties of integrated tropical peat soil in Malaysia. Electronic Journal of Geotechnical Engineering, 22, 457-466.

Zainorabidin, Adnan & Zolkefle, Siti Nurul Aini, 2014. Dynamic behaviour of Western Johore Peat, Malaysia. In: 3rd International Conference on Civil Engineering (CICCEN 2014), 29-30 November 2014, Mauritius. (http://eprints.uthm.edu.my/id/eprint/6730/).

*Manuscript received 24 November 2019*
*Revised manuscript received 13 June 2020*
*Manuscript accepted 20 June 2020*