UNIVERSITI PUTRA MALAYSIA

ELECTRO-OSMOTIC PROPERTIES AND EFFECTS OF pH ON GEOTECHNICAL BEHAVIOUR OF PEAT

AFSHIN ASADI

ELECTRO-OSMOTIC PROPERTIES AND EFFECTS OF pH ON GEOTECHNICAL BEHAVIOUR OF PEAT

By

AFSHIN ASADI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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To my beloved wife Shadi Yavari and my daughter Ava Asadi

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

ELECTRO-OSMOTIC PROPERTIES AND EFFECTS OF pH ON GEOTECHNICAL BEHAVIOUR OF PEAT

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April 2010

Chairman : Professor Dr. Bujang Kim Huat

Faculty : Engineering

Peat is an accumulation of partially decayed vegetation matter with high non-crystalline colloid which is formed in wetland systems. Using electro-osmotic techniques to improve peat entails developing a fundamental understanding of the electro-osmotic environment in peat which is an excellent context for this study. Electro-osmotic properties, electro-osmotic experiments, and the physicochemical effects on the peat due to electro-osmotic treatment were investigated. In addition, chemico-geomechanical sensitivities of peat to pH gradients were examined. The electro-osmotic properties of peat in the presence of different cations were also modeled by means of artificial neural networks.

Soil samples were collected to evaluate the correlations between electro-osmotic parameters. Electro-osmotic apparatus were designed and developed specific to provide conditions to get a good quality of undisturbed non-homogeneous samples. Electro-osmotic experiments were then conducted on the peat. To determine the

physicochemical effects on the peats due to electro-osmotic treatment, different undisturbed specimens were treated for short and long periods of time in the presence of peat water. Since the foremost effective mechanism during electro-osmotic treatment was electrolysis reactions at the electrodes, chemico-geomechanical sensitivities of peat to pH gradients were also investigated in the process. A backpropogation neural network was applied to model the electro-osmotic properties.

The results of the study showed that the zeta potential, specific surface area, water contents, and liquid limit increased as the organic content increased. The negative charge in peat was highly pH-dependent and surface charge dropped to zero at pH 2.3 to 3.5. The zeta potential of the peat was affected by the type of cations, the pH, the valance of cations, the concentration of the cations, degree of humification, and hydrated radius of the cations. The greater degree of humification resulted in the higher zeta potential. The trivalent cations showed a higher power in decreasing the zeta potential. The lower hydrated radius when the cations had the same valance showed a higher power in the decrease of the zeta potential. The higher concentration of the cations resulted in the lower zeta potential. The peat with the higher water content, temperature, and porosity showed the lower resistivity, while the higher organic content showed a contrary effect. The resistivity decreased as the degree of humification increased.

The study revealed that the greater degree of humification resulted in higher electro-osmotic permeability. The electro-osmotic treatment strengthened the peat at the

anode. The undrained shear strength and liquid limit of the peat were improved and the cation exchange capacity and zeta potential decreased as the pH decreased. The undrained shear strength and liquid limit decreased and the cation exchange capacity and zeta potential increased in the vicinity of the cathode.

Chemico-geomechanical effects of peat water pH gradients on peat revealed that in both fibrous and amorphous peat, the permeability and coefficient of volume compressibility increased and optimum moisture content decreased because of the acidic conditions, while the basic conditions had a contrary effect. The peats did not show any positive surface charge even at very low pH. The sensitivity of the amorphous peat to the electro-osmotic environment was higher than the sensitivity of the fibrous peat to the pH gradients. Electro-osmotic environment resulted in the charge neutralization, and increased the potential ability of the peats for a mechanical densification. The artificial neural networks results were found to be close to test values.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai mementuhi keperluan untuk ijazah Kedoktoran

SIFAT-SIFAT ELEKTRO-OSMOTIK DAN KESAN pH TERHADAP KELAKUAN GEOTEKNIKAL KEATAS GAMBUT

By

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Pengerusi : Profesor Dr. Bujang Kim Huat

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Gambut adalah pengumpulan jirim tumbuh-tumbulan yang mereput dengan koloid bukan-kristal yang tinggi. Menggunakan teknik elektro-osmotik untuk memajukan gambut memerlukan pembangunan pemahaman asas persekitaran elektro-osmotik di dalam gambut yang mana adalar satu konteks yang baik untuk kajian ini. Sifat-sifat elektro-osmotik, eksperimen elektro-osmotik dan kesan-kesan fizik-kimia terhadap gambut disebabkan oleh rawatan elektro-osmotik juga dikaji. Tambahan lagi, kepekaan kimia geomekanik gambut terhadap kecerunan pH juga dikaji. Sifat-sifat elektro-osmotik gambut dengan kehadiran kation-kation yang berbeza juga dimodelkan dengan menggunakan rangkaian neural tiruan.

Sampel-sampel tanah dikumpulkan untuk menilai hubungkait di antara parameter-parameter elektro-osmotik. Radas-radas elektro-osmotik dicipta dan dibangunkan khusus untuk memberikan keadaan-keadaan bagi mendapatkan kualiti sampel-sampel yang tidak terganggu bukan seragam yang baik. Eksperimen-eksperimen elektro-osmotik kemudian dijalankan pada gambut. Untuk menentukan kesan-kesan

fizikal-kimia terhadap gambut desebabkan oleh rawatan elektro-osmotik, spesimen tidak terganggu yang berbeza dirawat dalam tempoh masa yang singkat dan panjang dengan kehadiran air gambut. Disebabkan mekanisma yang paling efektif semasa rawatan elekto-osmotik ialah tindakbalas-tindakbalas eletrolisis pada elektrod-elektrod, kesensitifan geomekanikal gambut terhadap kecerunan pH juga disiasat dalam proses tersebut. Rangkaian neural Backpropogation telah digunakan untuk memodelkan sifat-sifat elektroosmotik.

Keputusan kajian menunjukkan bahawa potensi zeta, kawasan permukaan khusus, kandungan air dan had cecair meningkat apabila kandungan organik ditingkatkan. Cas negatif di dalam gambut sangat bergantung pada pH dan cas permukaan telah turun kepada sifar pada pH 2.3 hingga 3.5. Potensi zeta gambut dipengaruhi oleh jenis-jenis kation, pH, valensi-valensi kation, kepekatan-kepekatan kation, darjah pereputan dan jejari terhidrat kation-kation. Peningkatan darjah pereputan menyebabkan peningkatan potensi zeta. Kation-kation trivalent menunjukkan kuasa yang tinggi dalam menurunkan potensi zeta. Semakin rendah jejari terhidrat apabila kation-kation mempunyai valensi yang sama menunjukkan kuasa yang lebih tinggi dengan penurunan potensi zeta. Kepekatan kation yang tinggi telah menyebabkan penurunan potensi zeta. Gambut dengan kandungan air, suhu dan saiz liang yang lebih tinggi menunjukkan ketahanan yang lebih rendah manakala bagi kandungan organik yang semakin tinggi menunjukkan kesan yang berlawanan. Ketahanan menurun apabila darjah pereputan meningkat.

Kajian menunjukkan bahawa semakin tinggi darjah pereputan menyebabkan konduktiviti elektro-osmotik yang lebih tinggi. Rawatan elektro-osmotik menguatkan gambut pada anod. Kekuatan ricih tak tersalir dan had cecair gambut diperbaiki dan kapasiti pertukaran kation dan potensi zeta menurun apabila pH menurun. Kekuatan ricih tak tersalir dan had cecair menurun, dan kapasiti pertukaran kation serta potensi zeta pada sekeliling katod meningkat.

Kesan-kesan kimia-geomekanikal kecerunan pH air gambut menunjukkan bahawa di dalam kedua-dua gambut berserat dan amorf ketelusan dan pekali kebolehtekanan meningkat dan kandungan kelembapan optimum menurun disebabkan oleh keadaan berasid, manakala keadaan-keadaan asas menunjukkan kesan yang berlawanan. Gambut-gambut tersebut tidak menunjukkan sebarang cas permukaaan positif walaupun pada pH yang rendah. Kepekaan gambut amorf terhadap persekitaran elektro-osmotik adalah lebih tinggi berbanding dengan kepekaan gambut berserat terhadap kecerunan pH. Persekitaran elektro-osmotik menyebabkan peneutralan cas dan peningkatan kebolehan potensi gambut untuk penebalan mekanikal. Keputusan rankaian tiruan naural yang ditemui menghampiri nilai-nilai ujian.

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Thank you MALAYSIA.

I certify that a Thesis Examination Committee has met on 29 April 2010 to conduct the final examination of Afshin Asadi on his thesis entitled "Electro-osmotic Properties and Effects of pH on Geotechnical Behaviour of Peat" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, or is not concurrently, submitted for any other degree at University Putra Malaysia or at any other institution.

AFSHIN ASADI

Date: 13 May 2010

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