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I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science in Civil Engineering.

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I hereby declare that the work in this 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 concurrently submitted to any other degree at Universiti Malaysia Pahang or any other institutions.

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THE COMPATBILITY OF OSMOTIC AND VAPOUR EQUILIBRIUM TECHNIQUES IN ESTABLISHING SOIL-WATER CHARACTERISTICS CURVE: A CASE STUDY FOR BENTONITE

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ABSTRAK

Penggunaan betonit digunakan secara meluas dalam aplikasi kejuruteraan awam untuk tujuan geoalam sekitar dalam rawatan, pemulihan dan pengawalan sisa. Betonit dalam pelbagai bentuk biasa digunakan untuk membendung, bahan penampan di tapak pelupusan dan repositori bahan buangan nuklear (HLW). Pencirian betonit tempatan sedia ada adalah penting untuk pembangunan repository bahan buangan nuclear (HLW) di Malaysia. Beberapa penyelidik telah menunjukkan bahawa struktur tanah, kandungan air awal, mineralogi, ketumpatan, sejarah tekanan, mengisi tekanan dan pemadatan mempunyai pengaruh utama pada lengkung ciri tanah-air (SWCCs). SWCCs sering dikaji di makmal untuk anggaran tak tepu fungsi sifat tanah. Dalam mencirikan dan mewujudkan SWCCs kandungan sedut air, teknik keseimbangan osmosis dan wap (VET) digunakan secara meluas. Masalah yang berkaitan dengan intrusi polietilena glikol (PEG) ke dalam spesimen tanah menggunakan teknik osmosis di sedutan gunaan tinggi yang boleh menyebabkan kemusnahan membran separa telap, menjadikan ia sensitif kepada pencerobohan mikrob dan menjejaskan SWCCs ditubuhkan. Dalam kajian ini, pencirian fizikal, kimia, mineralogi dan mikrobiologi betonit Andrassy ditentukan mengikut prosedur standard. Sementara itu, terdapat dua kaedah pembasmian kumantelah digunakan untuk menghapuskan mikrob dengan menggunakan antimikrobial dan sinaran ultraungu (UVGI). Di samping itu, SWCCs kandungan sedut air semasa proses pengeringan dan pembasahkan telah dibentuk menggunakan teknik osmosis dan teknik wap (VET) pada sedutan gunaan daripada 0.15 hingga 262.75 MPa. Dalam usaha untuk mengurangkan kesan intrusi PEG dalam ujian osmosis, percubaan telah dibuat untuk menilai keberkesanan antimikrobial dan pendedahan sinaran ultraungu (UVGI) daripada kehadiran mikrob potensi pengurai mikrob tanah. Tiga jenis antimicrobial iaitu penisilin, iodin dan minyak kayu putih. Ujian kepekatan minimum (MIC) telah dijalankan ke atas ketiga-tiga antimikrobial dalam larutan PEG menggunakan kepekatan yang berbeza-beza daripada 10, 20, 40, 80, 160 dan 200 ul, manakala pendedahan sinaran ultraungu (UVGI) dijalankan mengikut pendedahan yang berbeza-beza iaitu 5, 10, 15, 30, 60 minit. Berdasarkan keputusan ujian, Andrassy betonit boleh diklasifikasikan sebagai tanah liat dengan keplastikan tinggi kerana mempunyai kapasiti tinggi kation pertukaran (CEC) dan ciri-ciri caj permukaan yang tinggi. Ujian analisis kimia menunjukkan bahawa betonit ini adalah berasaskan natrium monovalen betonit. Sebanyak lapan mikrob ditentukan dari spesimen tanah. Kandungan air untuk betonit yang diperolehi daripada ujian osmosis didapati lebih rendah daripada kandungan air yang diperoleh daripada ujian keseimbangan wap (VET) pada sedutan 3.65 hingga 9.96 MPa. Intrusi PEG dapat dikesan. *Paecilomyces lilacinus* dan *Trichoderma atroviridae* mungkin bertanggungjawab ke atas pengurai membran separa telap selulosa acetat yang digunakan dalam ujian osmosis. Berdasarkan hasil kajian ini, pendedahan sinaran ultraungu (UVGI) selama 10 minit merupakan cara paling berkesan menghapuskan semua mikrob dan mengurangkan kesan intrusi PEG. Kandungan sedut air yang lebih tepat telah dibentuk untuk betonit selepas terdedah dengan sinaran ultraunga (UVGI) dan dengan itu memperbaiki keserasian antara kedua-dua teknik pada sedutan tinggi.

ABSTRACT

The use of bentonite has been widely applied in geoenvironmental engineering applications for treatment, remediation and waste control. Bentonites in various forms are commonly used for containment, buffer material in landfills and high level nuclear waste (HLW) disposal repositories. Characterisation of locally available bentonite is crucial for development of HLW repository in Malaysia. Several researchers have showed that soil structure, initial water content, mineralogy, density, stress history, confining stress and compaction have considerable influence on the soil-water characteristic curves (SWCCs). SWCCs are frequently being established in the laboratory for estimation of unsaturated soil behaviour functions. In characterizing and establishing suction-water content SWCCs, osmotic and vapour equilibrium techniques (VET) are widely used. Problem associated with an intrusion of polyethylene glycol (PEG) into soil specimen in osmotic tests at high applied suction that may cause the degradation of the semi-permeable membrane, thus making it sensitive to microbial attack and affecting the SWCCs established. In this study, the physical, chemical, mineralogical and microbiological properties of Andrassy bentonite were determined following the standard procedures. Meanwhile, there were two disinfections methods were used to eliminate microbes by using antimicrobial and Ultra-Violet Germicidal Irradiation (UVGI) Exposure. Besides that, the suction-water content SWCCs during drying and wetting were established using osmotic and vapour equilibrium techniques at applied suctions of 0.15 to 262.75 MPa. In order to minimise the effect of PEG intrusion in osmotic test, an attempt was made to evaluate the effectiveness of antimicrobials and UVGI exposure in removal of cellulose degrading soil microbes. Three types of antimicrobial were considered namely penicillin, iodine and eucalyptus oil. Minimum Inhibitory Concentration (MIC) tests were conducted on all three antimicrobials in PEG solutions with varying concentrations of 10, 20, 40, 80, 160 and 200 μl, whereas UVGI exposure was carried out at different exposure time of 5, 10, 15, 30, 60 minutes. Based on the results, Andrassy bentonite can be classified as clay with high plasticity due to high cation exchange capacity (CEC) and high surface charge characteristics. The bentonite predominantly consists of montmorillonite mineral (63.2%). Chemical analysis indicated that the bentonite is sodium based monovalent bentonite. A total number of eight microbes were determined from the soil specimen. Water contents for the bentonite obtained from osmotic tests were found to be lower than water contents obtained from vapour equilibrium tests at applied suction of 3.65 to 9.96 MPa. Intrusion of PEG was observed. *Paecilomyces lilacinus* and *Trichoderma atroviridae* may be responsible for the degradation of cellulose acetate membrane used in the osmotic tests. Based on the findings of this study, UVGI exposure of 10 minutes was found to be the most effective method in eliminating all microbes and minimised the effect of PEG intrusion. A more precise suction-water content SWCC was established for the bentonite after UVGI exposure and thus improved the compatibility of both techniques at higher applied suctions.

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LIST OF SYMBOLS

%	Percent
MPa	Mega Pascal
Ua	Air Pore Pressures
Uw	Pore Water Pressures
kPa	Kilo Pascal
Rh	Hydrodynamic Radius
nm	Nanometre
µm	Micrometre
g	Gram
mm	Millimetre
°C	Degree Celsius
V	Volume
ml	Millilitre
kV	Kilovolt
mA	Milliamphere
PEG/g	Polyethylene Glycol per gram
m^2/g	Square metre per gram
m^2/s	Square metre per second
meq/100g	Milliequivalents per 100 grams
TiO_2	Titanium dioxide
$CaCl_2$	Calcium Chloride
LiCl	Lithium Chloride
KCl	Potassium Chloride
NaCl	Sodium Chloride
K_2SO_4	Potassium Sulphate
K_2CO_3	Potassium Carbonate
KNO_3	Potassium Nitrate
Si	Silicon
NaCl	Sodium Chloride
Fe_2	Ferric Ion
Mg	Magnesium
Ca	Calcium
Na_2	Sodium Ion

Mn	Manganese
Fe	Iron

LIST OF ABBREVIATIONS

AFM	Atomic Force Microscopy
BET	Brunauer-Emmett-Teller Adsorption
CEC	Cation Exchange Capacity
EGME	Ethylene Glycol Monoethyl Ether
FTiR	Fourier Transformation Infrared
HLW	High Level Nuclear Waste
ICP-OES	Inductively Coupled Plasma- Optical Emission Spectroscopy
LOI	Loss of Ignition
MICs	Minimum Inhibitory Concentration
MW	Molecular Weights
MWCO	Molecular Weight Cut Off
NA	Nutrient Agar
PDA	Potato Dextrose Agar
PEG	Polyethylene Glycol
SEM	Scanning Electron Microscopy
SPM	Scanning Probe Microscopy
SSA	Specific Surface Area
SWCC	Soil-Water Characteristic Curves
UMP	Universiti Malaysia Pahang
USA	United States of America
UV	Ultra Violet
UVGI	Ultra Violet Germicidal Irradiation
VET	Vapour Equilibrium Technique
XRD	X-Ray Diffraction
XRF	X-Ray Fluorescence
XPS	X-Ray Photoelectron Spectroscopy

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