

An experimental study of the hydro-mechanical and electrical properties of peat*

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Abstract: Peats are structured and highly complex porous media, with unique hydro-mechanical responses. The complex behaviour of peats is affected by several soil properties, such as soil fabric, void ratio, and fibre content. The induced polarization (IP) technique measuring the real (σ') and the imaginary part (σ'') of the complex electrical conductivity has been used to estimate the physical, chemical and hydrogeological properties of rock and soils. However, the relationships between electrical conductivity (σ' and σ'') and those peat properties are rarely known. For this purpose, a modified hydraulic oedometer cell with electrical measurement was built for laboratory investigation. A series of tests on natural and reconstituted peat samples were performed. The test results show that the fabric anisotropy of fibrous peats plays a crucial role in the hydro-mechanical and electrical conductivity anisotropy. The degree of anisotropy decreases gradually during the consolidation process, accompanied by a decrease in σ' , whereas the σ'' is not significantly affected. Both the σ' and σ'' are strongly increased with pore fluid conductivity σ_w , approximating power-law dependence on σ_w .

Key words: electrical conductivity; soil fabric; anisotropic; pore fluid conductivity

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1 Introduction

The induced polarization (IP) technique has been used to estimate the physical, chemical and hydrogeological properties of rock and soils. IP measurements provide information about the electrical conductivity and the capacitive properties of the ground, which can be expressed, respectively, in terms of the real (σ') and imaginary (σ'') components of the complex conductivity (Slater and Reeve, 2002; Binley and Kemna, 2005). The σ' is mainly associated with conductive properties, whereas the σ'' accounts solely for the polarization effects of soil constituents. The main objective of this study is to investigate the possi-

bility of characterizing the properties of peat, providing a useful tool for ground investigation and peat classification with the use of the IP technique.

Peats are characterized by high water content, organic content, strong compressibility, anisotropy and sensitivity to oxidation. Fibrous peat particles have a hollow cellular structure largely full of water, with a supporting matrix made of organic materials that are the partially decomposed remains of plants. The multiporosity structure has been confirmed by many researchers (Kazemian et al., 2011; Zhao et al., 2021), which includes highly irregular and interconnected large pores, as well as smaller open pores, dead-end pores, and isolated closed or partially closed pores

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(Quinton et al., 2009; Rezanezhad et al., 2010; Muraro and Jommi, 2021).

Water in peat can be present in three states: water in interconnected inter-particle pores, which can actively transmit water; water within organic peds and fibrous components, and absorbed water (bounded water). The electrical conductivity of peat results from the electrical conductivity of its components (i. e., fibers, organic peds and water properties) and the structure. A peatland is a dynamic system due to the decomposition of organic matter by microflora, bacteria and fungi. Peat undergoes a physical and chemical change over time, the fibre of peat going from a fibrous structure to a granular isotropic state. During the anaerobic degradation, biogenic gas and dissolved humic acids are produced, accompanied by an increase in charged organic acid functional groups as peat decomposes (Comas et al., 2004; Mesri and Ajlouni, 2007; Ponziani et al., 2012). A change in electrical conductivity and an induced polarization response is expected as the physical and chemical changes occur during the degradation. These pose challenges to engineers in describing subsurface peat structures and predicting their behavior over time.

Fibres are considered to be of special interest for peats, as they allow fabric arrangements different from those of mineral soils, and they are claimed to be responsible for particular aspects of their hydro-mechanical response (Kumar et al., 2006; Mesri and Ajlouni, 2007; Hendry et al., 2012; Zhao and Jommi, 2020). The structured, fibrous peaty material shows strongly cross-anisotropic properties, arising from the general horizontal alignment of the constituent fibres (Zwanenburg, 2005). In the field, anisotropy in electrical conductivity is important as the electrical resistivity measured in the field represents a spatial average of the field electrical-resistivity tensor. This averaging relative to the degree of anisotropy must be assessed before IP surveys can be used in the field for assessing construction quality. However, an understanding of the anisotropic electric conductivity behavior in peats has been lacking. Moreover, the fibre and the fabric will rearrange upon loading, as peats are very compressible materials and may induce stress-induced fabric rearrangement, which needs to be investigated.

To assess electrical geophysical data obtained in peatlands, one must know how the physical and chemical properties of peat relationships link electrical measurements. In this study, a new consolidometer cell with associated tools for simultaneous geo-mechanical and electrical measurements was developed. The correlations between the electrical conductivity of peat and index properties (e. g., fabric anisotropy and void ratio) and pore fluid conductivity are investigated.

2 Materials and methods

2.1 Tested materials

The peat used in this investigation was collected at the Leendert de Boerspolder site in the Netherlands. The natural samples were retrieved using a 106 mm diameter piston sampler. The soil cores were sealed on both ends with wax and transported back to the laboratory. To reduce biodegradation, the material was stored in a climate-controlled room at $10 \pm 1^\circ\text{C}$ and 90% relative humidity. The natural samples for laboratory tests were trimmed after the samples were extracted. To obtain the natural sample for the oedometer test, the thin-wall consolidation ring has an internal diameter of 80 mm and a height of 140 mm and is used to retrieve the sample directly from the natural samples from a piston sampler (Fig. 3). Reconstituted samples were prepared by mixing the material with demineralised water to form a slurry with a water content of 855%, corresponding to 1.4 times the liquid limit. The slurry material has been placed into a floating consolidometer tube and subjected to vertical stress of 10 kPa through deadweights as preloading for 48 hrs. The reconstituted sample was then extracted and trimmed into a consolidation ring for the 1-D oedometer test, and the residue of the sample has been collected and tested for index properties. The initial void ratio e_0 of the extracted sample is calculated. The initial water content (w_0), specific gravity (G_s), organic content (OM), and fibre content (FC) were determined for each sample. Oven-drying procedures for soil classification were performed at a temperature of 60°C to prevent oxidation of the organic matter. The specific gravity was measured with a gas expansion ultrapycnometer (ASTM, 2014). Loss on ignition

was determined by placing a small amount of oven-dried sample in a muffle furnace at 500 °C for 5 hours. The fibre content is defined as the percentage of the dry mass of fibres retained by the ASTM no.100 sieve (ASTM,2013). The studied natural peats represent sphagnum peat and the fibrous structure is preserved with an average fibre content of 14% and 91% organic content.

2.2 Test apparatus

This part presents new equipment, which has been realized for simultaneous monitoring of the electrical and geo-mechanical properties of soil. The apparatus is a modified hydraulic oedometer implemented with pore-pressure control, a back-pressure facility, and two electrode porous copper plates for multi-frequency complex conductivity measurements during compression of the sample. The schematic diagram of the new cell is represented in Fig. 1. The cell consists of polyvinyl chloride (PVC) ring with an in-

ternal diameter of 80 mm and a height of 140 mm to host the soil sample. The cell ring is connected to the top and bottom with bolts and sealed with two O-rings. A sample that fills in the cell is constricted by two porous plates at the top and bottom of the sample. The top plate moves down and up when loading and unloading. One GDS advanced controller connects to the top of the cell and measures the volume change. The other GDS advanced controller connects through the drainage tube at the bottom and works as a back-pressure system to control the saturation of the soil sample. The vertical load is applied by adding weight to the frame. A back pressure of 180 kPa is used to saturate the sample and balance the weight of the frame. Pore pressure is measured at the bottom through pore pressure transducers. The displacement is measured by the LVDT placed on the top of the frame.

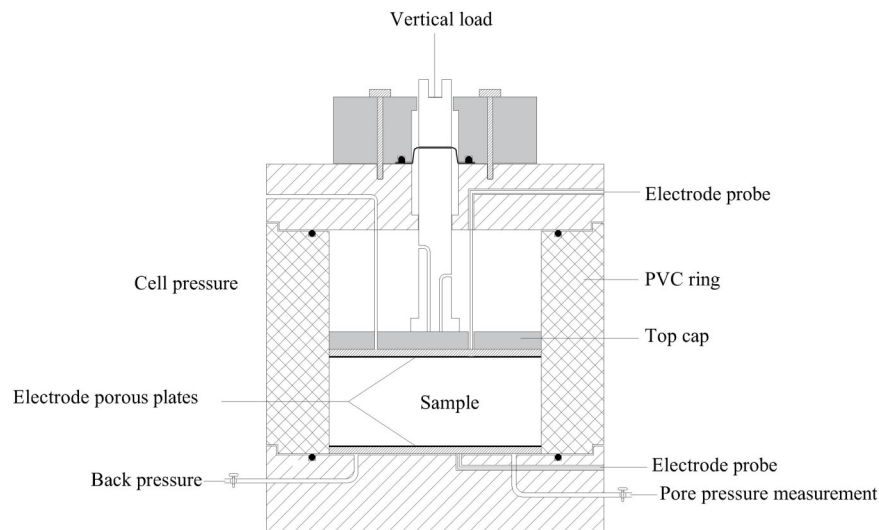


Fig. 1 Schematic diagram of the prototype cell

Another function of the cell is to act as a capacitor to achieve measurements of the electrical properties of the soil sample. The sample inside the cell acts both as a dielectric medium and a conduction path between the two electrode porous plates. Since the electrical resistivity of a PVC cell is about 10^{12} to $10^{14} \Omega \cdot \text{m}$, the cell electrically insulates the sample to ensure it measures the electrical potential correctly. Four electrodes are connected to a precision component analyzer (6440A, Wayne Kerr Electronics Ltd.) for in-

jecting current and acquiring potential between the two electrode porous plates. One couple of electrodes is used to inject the alternating electric current (AC) into the sample, while the other couple of electrodes is used to measure the electric potential difference between them. The analyzer can operate at frequencies from 20 Hz to 3 MHz, accepting arbitrary multi-frequency steps and allowing for the acquisition of capacitance (C), resistance (R_0), impedance amplitude ($|Z|$) and phase angle (θ). The frequency dependence

of the real (σ') and imaginary parts (σ'') of the complex conductivity (σ^*) corresponds to induced polarization phenomena. The real part σ' relates to the in-phase conductivity component, i. e., ohmic conduction or energy loss term, while the imaginary part σ'' corresponds to the out-of-phase conductivity component, i. e. polarization or energy storage term. The σ' and σ'' components of the complex conductivity σ^* can be computed from the measured phase angle (θ) and amplitude ($|Z|$) of the impedance according to the geometrical factor, which is the ratio between the electrode distance (d) and the electrode area (A):

$$\sigma^* = \sigma' + i\sigma'' = \frac{\cos(-\theta)}{|Z|} \frac{d}{A} + i \frac{\sin(-\theta)}{|Z|} \frac{d}{A},$$

where $i = \sqrt{-1}$ is the imaginary unit, and $\theta = \tan^{-1}(\sigma''/\sigma')$.

Calibration of the electrical system with fluids of known conductivity is necessary to study the accuracy of the measurements. Specifically, a reliable frequency range in which the electrode polarization effect is negligible must be determined, which accounts for the different electric field distributions as a function of electrode spacing. For this purpose, tests on demineralized water with a conductivity of 0.0026 S/m were carried out. These measurements have been carried out for five electrode distances: 10, 20, 30, 40 and 48 cm, respectively. Fig. 2 shows the theoretical and measured real parts of the conductivity σ' and phase angle θ of demineralized water as a function of the distance between the electrode plates. The results show that at low frequencies, the θ tends to zero, and the system becomes purely resistive. At high frequencies, the capacitance dominates as the θ tends to 90° . Thus, the relative error in the capacitance is expected to increase at low frequencies, whereas for the resistance, this will occur at high frequencies due to the capacitive coupling effect. As shown in Fig. 2, below frequencies of 1000 Hz, the error in σ' and θ is low in the frequency range of the measurements (20– 3×10^6 Hz). The system is effective for determining the real conductivity below 10000 Hz. In this paper, the electricity measured at 2000 Hz is reported.

2.3 Test procedures

The natural or reconstituted samples are retrieved by the thin-wall consolidation ring having an

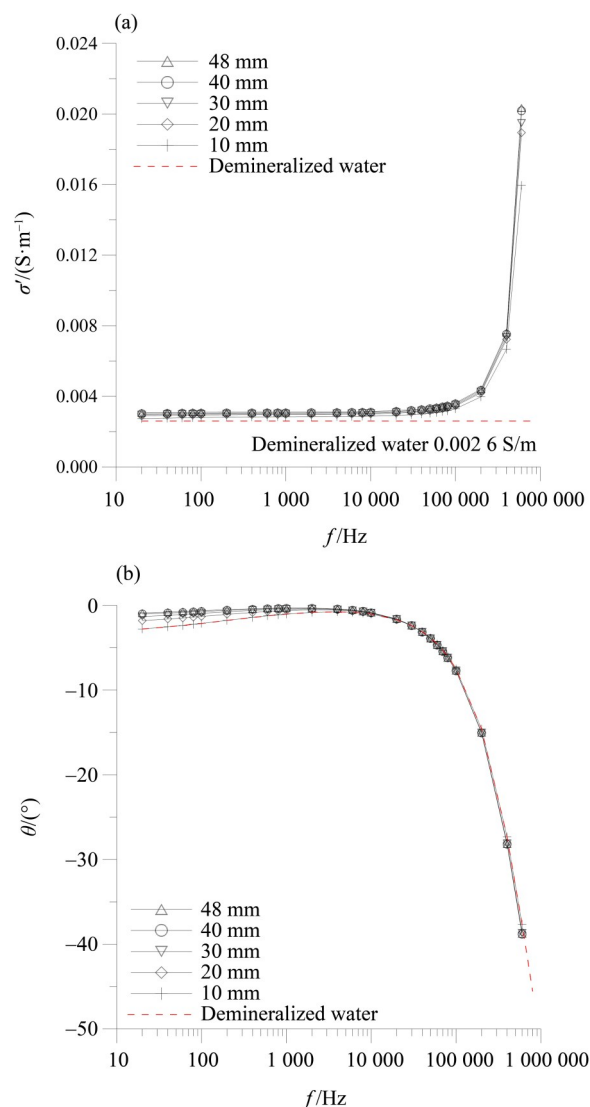


Fig. 2 Calibration curves obtained from the measurements on distilled water: (a) theoretical curves of σ_w are compared with experimental data; (b) measured phase angle

internal diameter of 80 mm and a height of 140 mm for the 1-D oedometer test. After mounting the sample and setting up the device, a back pressure of 180 kPa is applied to saturate the sample and balance the weight of the frame. Then, the sample inside the cell is compressed by incremental vertical loading. The excess pore water pressure and volume change are continuously measured during the test, when the pore water pressure keeps constant with drying time, then the consolidation stage is assumed to be finished. The test was performed at a controlled air temperature of $(14 \pm 1)^\circ\text{C}$ and a relative humidity of 80%. The compression data is used to determine the consolidation parameters and hydraulic permeability of a soil

sample. The complex electrical conductivity measurement is conducted at the end of each loading step. Thus, the cell makes it possible to correlate the electrical properties of a sample with its physical, mechanical, and hydrological properties by measuring them simultaneously on the same sample.

3 Results and discussion

3.1 Effect of the initial fabric of peat

Fig. 3 shows the natural sample retrieved from piston sampler B1003-4 for laboratory testing. The samples are denoted by the borehole number and the

tube number. Two series of tests were performed to study the role of the fabric in the hydro-mechanical and electrical behaviour of peat soils. The first series aims at investigating the role of the natural fabric by comparing the results of the undisturbed samples to the reconstituted samples of the same peat. The second series focuses on the contribution of the alignment of the fibres and pore structure to the overall structure by trimming the natural sample B1003-4 and the reconstituted sample vertically and horizontally. The properties of the tested peat samples are shown in Table 1.

Table 1 Properties of the tested peat samples in different directions

Samples	Sample status	e_0	σ'_v / kPa	λ	κ	
B1003-4	vertical	natural	13.42	20	$\lambda_v=3.22$	$\kappa_v=0.17$
	horizontal	natural	13.96	7	$\lambda_H=2.97$	$\kappa_H=0.17$
Reconstituted	vertical	reconstituted	9.67	10	$\lambda_v=1.52$	$\kappa_v=0.13$
	horizontal	reconstituted	8.99	10	$\lambda_H=1.54$	$\kappa_H=0.15$
B1003-4 flush with water	natural	13.5	–	–	–	

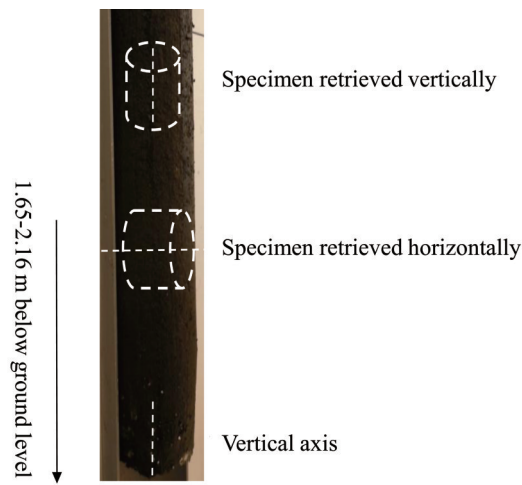


Fig. 3 Natural samples from a piston sampler were retrieved vertically and horizontally

3.1.1 Microstructure of the natural and reconstituted peat

To assist in the interpretation of the data and to visualise the fabric of peat, the microstructures of natural and reconstituted samples were investigated using Micro-Computer Tomographic images. The difference between the natural and reconstituted samples is that the natural physical state and arrangement of components have been destroyed by reconstitution. Fig. 4 displays the cross-section photos and pictures

obtained from X-ray micro-computed tomography (CT) on the natural and reconstituted peat, after 2 days of drying at a temperature of 14 °C and relative humidity of 80%. In the natural sample, typical aggregated structures of natural organic matter and fibrous texture are identified, with a predominant amount of fine fibres and a few big reed fibres. As observed from the retrieved samples, the fibres are predominantly horizontally orientated. The skeleton of the natural peat sample is mainly composed of organic aggregates, with fibres randomly distributed in between. Together with the hollow structure of the fibres, organic peds with small inner pores can be distinguished. Large inter-peds pores are visible between the organic peds and between the organic peds and the fibres. As the intact fabric of the natural soil has been completely changed by reconstitution, a massive texture, a more densely packed arrangement, with inter-particle pores filled with the organic matter, is observed for a reconstituted sample. The small fibres seem to be diffuse and randomly distributed without an initial preferential orientation. Inorganic soil grains are visible with higher density (white spots) within the fibrous matrix.

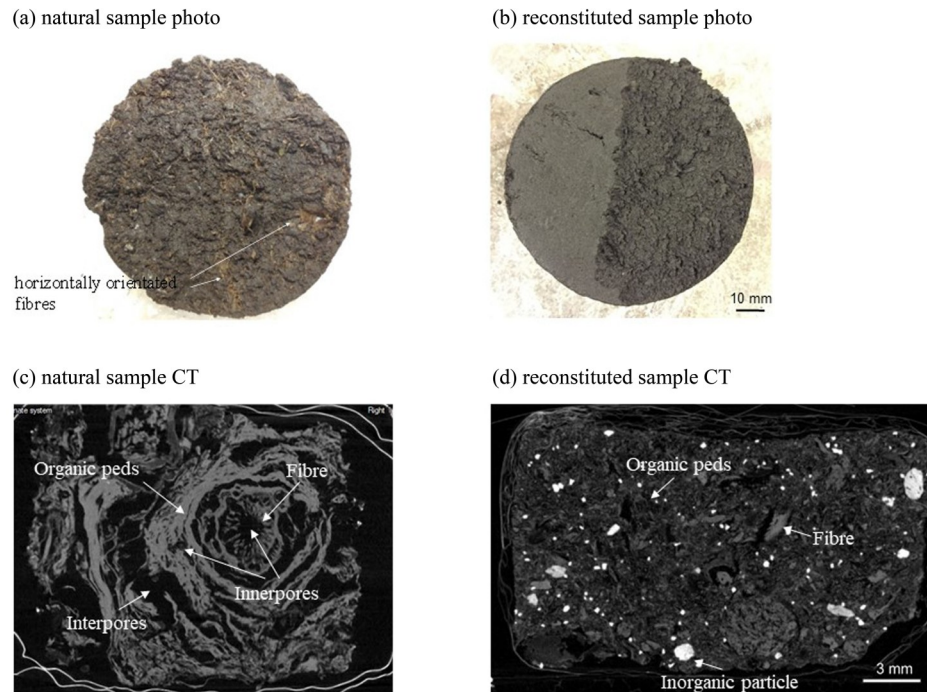


Fig. 4 Cross-section photos and CT scan of natural sample and reconstituted sample

3.1.2 The compression and hydraulic behaviour

Fig. 5(a) and (b) report the one-dimensional compression data for sets of natural and reconstituted samples prepared in vertical and horizontal directions. The natural samples show strongly cross-anisotropic behaviour. The two curves of reconstituted samples are almost identical, indicating isotropic behaviour. The compression curves show a typical S shape with a marked change in the slope corresponding to the yield stress, typically identifying a "structured" soil. They were derived using Casagrande's (1936) graphical construction and are reported in Table 1. The initial fabric of the natural sample is expected to remain relatively intact up to the yield stress and to be disrupted progressively once the yield stress is overpassed, causing the overall compressibility to increase substantially. For the samples in the natural state, the yield stress of the vertical trimmed sample (σ'_v) and the horizontal trimmed sample (σ'_h) direction is about 20 and 7 kPa, respectively. The B1003-4 is sampled between 1.65 m and 2.16 m below the ground surface. The original phreatic surface was located 0.4 m below the ground level in the polder. There is no evidence of any significant loading in the geological history of the studied soils. The in situ vertical effective (σ'_{v0}) is about 15-20 kPa which was calculated using

the bulk unit weights and groundwater level. The coefficient of earth pressure at rest, $k_0=0.33$ has been reported on the same tested peat soils by Muraro (2019). The corresponding horizontal stress level ranges from 7.5 to 10 kPa. The yield stresses obtained from the laboratory test was similar to the pressure that experienced overburden stress. The sample can reasonably be considered normally consolidated. Differently from the natural samples, the compression curves of the reconstituted samples tested vertically and horizontally are identical. The yield stress of the reconstituted sample is around 10 kPa, which is equal to the preloaded vertical stress.

The saturated compressibility of the different samples is compared using the loading index, $\lambda = -\Delta e / \Delta \ln \sigma'_v$, and the swelling index κ for unloading. The compression indexes of λ and κ of peat samples with different directions are summarized in Table 1. The natural samples give the soil a higher compressibility. The parameters followed by "H" are for the horizontally retrieved samples and "V" are for the vertically retrieved samples. The loading index of values λ for natural samples are $\lambda_v=3.22$ and $\lambda_h=2.97$, respectively. $\lambda_v=1.52$ and $\lambda_h=1.54$ are reported for reconstituted samples. The compressibility of the natural samples shows cross-anisotropic behaviour.

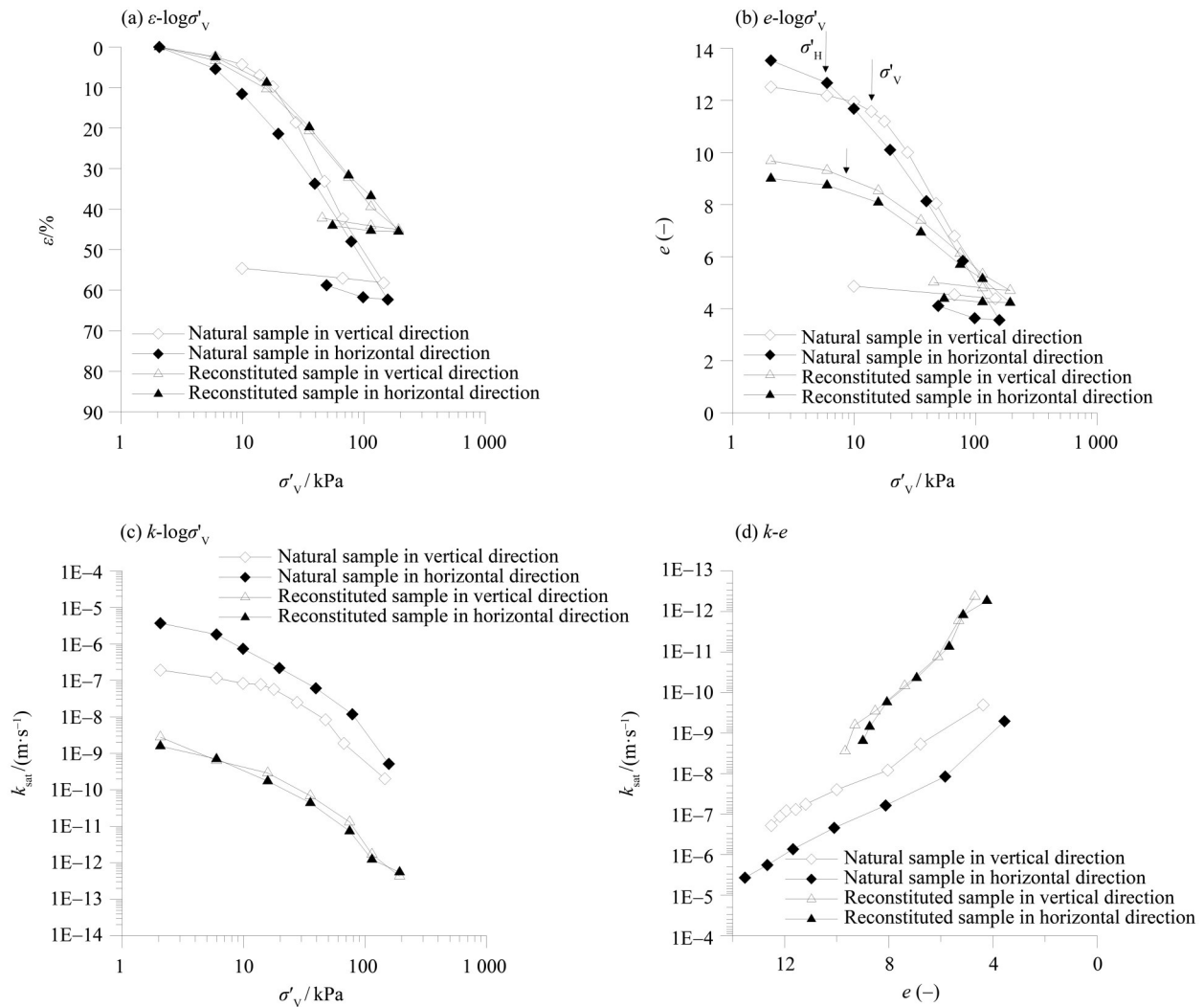


Fig. 5 The effect of sample direction on compression and hydraulic behaviour

Fig. 5(c) and (d) show how the vertical hydraulic conductivity, k , changes with vertical stress and void ratio. The k obtained has been analyzed by using Taylor's curve fitting method (log time method) as the pore pressure measurement can indicate the 100% degree of consolidation. It demonstrates the dramatic role of the initial fabric of the soil in its hydraulic conductivity. Natural peat has a high k in the order of 10^{-6} m/s, due to relatively large open pores. The k value is reduced by three orders of magnitude on average by remoulding the initial fabric of the soil. The natural sample shows that k of the vertical trimmed sample was lower than the horizontal trimmed sample, indicating that k of the studied peat behaves anisotropically. The anisotropy of natural samples is attributed to the predominantly horizontally-orientated fibres. The schematic diagrams of the vertically and horizontally retrieved natural samples are shown in Fig. 6.

The vertically retrieved natural sample has fibres horizontally aligned (Fig. 6(a)), whereas the horizontally retrieved natural sample has fibres vertically aligned (Fig. 6(b)). The orientation of fibres in the horizontally retrieved natural sample can greatly enhance the hydrological connectivity by creating vertically connected inter-pores that allow rapid water movement, giving a much higher k .

As shown in Fig. 5, at low stress levels (high void ratio), the natural peat samples show strongly anisotropic behaviour, and the level of anisotropy decreases with 1D compression loading. As a result, 1D compression loading causes a substantial reduction of the void ratio. The flow channels (inter-pores) were compressed, which reduced the k by several orders of magnitude, as shown in Fig. 5. The constituent fibres realign as the vertical stress increases. As shown in Fig. 6(a), compared with the initial configuration of

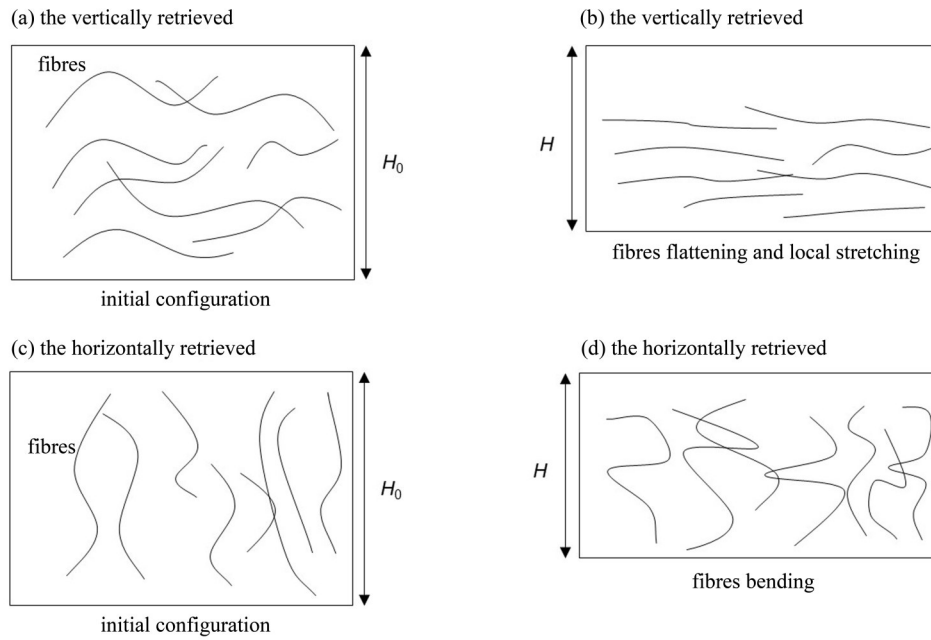


Fig. 6 The evolution of fibres in the natural peat sample during 1D consolidation

the vertical retrieved sample, fibres were flattening and local stretching as the sample was compressed with lateral confining. The compression of horizontally aligned inter-pores of vertically retrieved samples gives higher compressibility. For the horizontally retrieved natural sample, the fibres bent as the sample compressed (Fig. 6(b)). The flow channels will become more curved and longer. Thus, the reduction of k is more significant for the horizontally retrieved sample. The hydraulic behaviour became isotropic at higher effective stresses due to the development of a new stress-induced fabric. The degree of anisotropy decreases substantially after overloading. The curves describing the change in k with e tend to converge to the same final value. The fibres are randomly distributed in the reconstituted samples. The compression and hydraulic behaviour were largely isotropic, and the reduction in permeability followed the same trend for vertical and horizontal directions upon loading.

3.1.3 Effect of fabric on electric conductivity

The relationship between electrical and fabric anisotropies seems intuitive because the electrical conductivity of soils in general is strongly dependent on both the pore shapes and spatial arrangements. The electric conductivity of the samples was measured during consolidation. Fig. 7 displays the real and imaginary elec-

trical conductivity values ($f = 2\ 000\ \text{kHz}$) measured at the end of each loading step as a function of hydraulic conductivity k . During the injection of current into a peat sample, the current will pass through the water in the interconnected pores. The presence of the electrical double layer (EDL) formed at the solid-fluid interface of organic peds and fibrous components induce polarization response, and it is a function of the surface chemical properties, the pore solution chemistry, and the micro geometrical properties of the sample (Lesmes and Frye, 2001; Quinton et al., 2009; Rezanezhad et al., 2010; Muraro and Jommi, 2021). As shown in Fig. 8, the real part of conductivity σ' follows an almost linear relationship with k , which decreases with k as the resistance of the electric current path increases. However, the imaginary part of conductivity σ'' is related to the polarization of the electrical double layer formed at the solid-fluid interface, and it is not sensitive to compression. Yamaguchi (1992) investigated the change in pore size distribution under compression. The result showed that while the peat is compressed, the number of openings with a pore diameter of $100\text{--}10\ \mu\text{m}$ decreases and the diameters of the openings are converted into the second range of $1\text{--}0.1\ \mu\text{m}$. Changes in porosity influence the conductivity of peat, as pore-throat diameters and pore geometry of water-saturated geo-materials con-

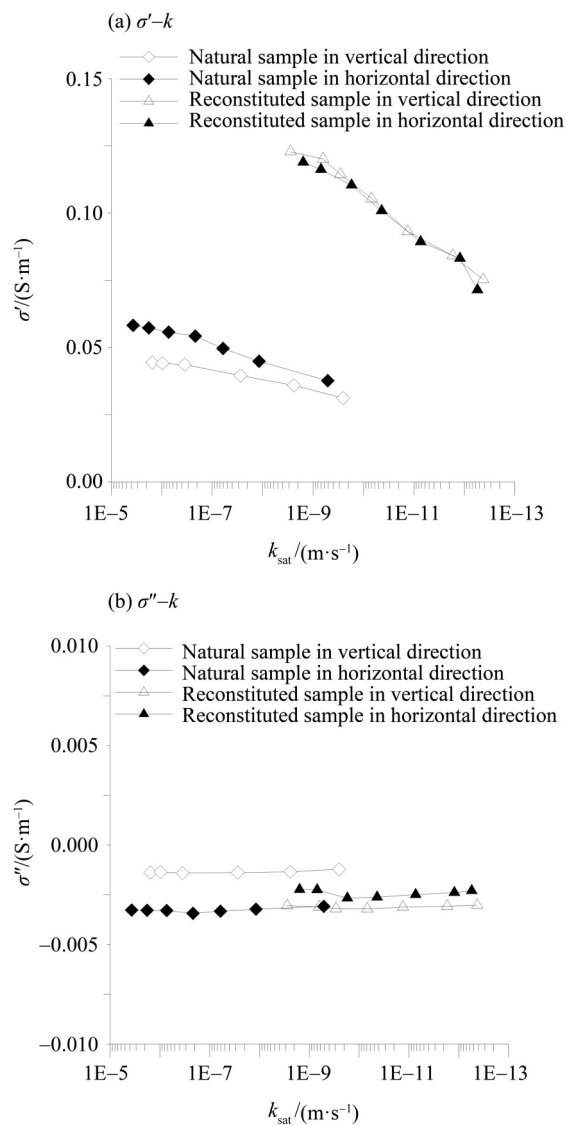


Fig. 7 The effect of microstructure on electrical conductivity

tribute significantly to the value of σ' .

In addition, the anisotropic texture of peat influences the electrical properties. The real part of the electric conductivity σ' of the natural sample exhibits anisotropic behaviour. It is also found that the σ' of the vertical trimmed sample and the horizontal trimmed sample start to converge on each other after the compression load is applied. It indicates that the degree of anisotropy of the real part of conductivity σ' decreases with loading. Differing from the real part of conductivity, no anisotropy is found in the imaginary part of conductivity σ'' for reconstituted samples.

3.2 Effect of pore fluid conductivity

Peat typically contains 85%–95% water by weight. About half of the water is in external pores; the remainder is within plant cells, bound chemically

with organic material or held in capillaries. The electric conductivity of peat is controlled by the mobility of the ions present in the fluid filling the pores. Field observations of the peat conductivity present very diverse values, from a few to hundreds of mS/m (e. g. Siegel and Glaser, 1987; Theimer et al., 1994; Comas et al., 2004), typically increasing with depth (Slater and Reeve, 2002). Pugh et al. (1996) reported that the concentration of chloride was as high as $3\,000\ \mu eq/L$ (approximately equivalent to $\sigma_w = 0.06\ S/m$) in a salt-contaminated peatland in Maine. However, extreme salt concentrations in peatlands due to contamination can reach more than $32\,000\ \mu eq/L$ ($\sigma_w > 1\ S/m$) (Wilcox, 1986). The electrical conductivity of water squeezed from the sampled peat soils was measured. The conductivity ranged from 600 to $3000\ \mu S/cm$. The conductivity of water from the peat sample in-situ also indicated that the pore fluid conductivity also changes with the location in the polder. The conductivity of pore fluid water is higher in the toe than on the polder side and the dyke. Under anaerobic conditions, the organic matter degrades with the production of biogenic gas and dissolved humic acids, which increases the pore fluid conductivity in peat samples. It can reach $20\,000\ \mu S/cm$ after samples stored 2 years later in an anaerobic condition, and the fibre content decreased from 40% to 20% was observed.

One natural peat sample under the same effective vertical stress (10 kPa) was flushed with 13 NaCl solutions of progressively increasing σ_w over the range of 100 to $100\,000\ \mu S/cm$. The NaCl solutions were flushed from the bottom and drained from the top of the sample. The conductivity of the outflow was constantly monitored until the fluid conductivity was stabilized at the inflow value. After that, the electricity of the samples was measured. The content of salt in water gives ions that are electrically charged and generate electrical currents. The electrical conductivity is proportional to the ions in water. The results are presented in Fig. 8, where the real and imaginary parts of the electrical conductivity of a peat sample are strongly increased with σ_w , approximating power-law dependence on σ_w . The power-law dependence on σ_w is 0.81 and 0.68 for σ' and σ'' , respectively. The electric conductivity represents the conduction of the

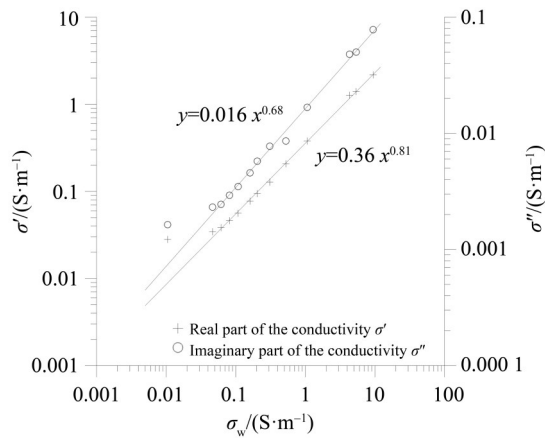


Fig. 8 The variation of electricity of peat sample with the conductivity of pore fluid

material, which is a function of both the bulk conductivity and surface conduction effects. The bulk conductivity increased as the pore fluid conductivity σ_w increased. The surface conductivity of peat is mainly due to the conduction of the counterions located in the fixed layer of charges of the EDL. An increase in σ_w causes an increase in the EDL ionic charge density. However, there is some deviation in the electric conductivity when the σ_w is lower. The deviation from linearity of the electric conductivity versus σ_w relationship is due to the dilation of macropore spaces (Ours et al., 1997). As detailed by the authors, an increase in the chloride solution concentration induced the flocculation of the organic acids located on the surfaces of peat fibres and subsequent dilation of macropore spaces. This flocculation was also noted in the laboratory experiments by the change in the effluent solution clarity from brown to clear with increasing chloride concentration.

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4 Conclusions

Peats are characterized by high water content, organic content, strong compressibility, anisotropy, and sensitivity to oxidation. The main objective of this study is to investigate the possibility of identifying the physical, chemical, and hydrogeological properties of peat by the induced polarization technique. For this purpose, a modified hydraulic oedometer cell with a complex electrical conductivity that comprises a real (σ') and an imaginary part (σ'') of bulk electrical conductivity measurement was built for laboratory investigation. The σ' is mainly associated with conductive properties, whereas the σ'' accounts solely for the polarization effects of soil constituents.

The effect of the fabric was investigated by comparing tests on the natural and reconstituted samples trimmed in vertical and horizontal directions. The test results show that the fabric anisotropy of fibrous peats plays a crucial role in the hydro-mechanical and electrical conductivity anisotropy. The anisotropy of natural samples is attributed to the predominantly horizontally-orientated fibres. As samples are compressed with lateral confining, new stress-induced fabric reduces the degree of anisotropy. The consolidation process is accompanied by a decrease in σ' , whereas the σ'' is not significantly affected due to the water mainly draining from the big inter-pores.

One natural peat sample was flushed with NaCl solutions of progressively increasing pore fluid conductivity σ_w over the range of 100 to 100 000 $\mu\text{S}/\text{cm}$. Both the σ' and σ'' is strongly increased with σ_w , approximating power-law dependence on σ_w .

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泥炭土的水力和电阻率特性试验研究

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摘要: 泥炭土是一种高度结构化, 复杂多孔介质, 具有独特的水-力特性。土体结构、孔隙比和纤维含量等物理性质对泥炭土的力学特性有十分重要的影响。感应极化 (IP) 技术通过测量电导率的实部 (σ') 和虚部 (σ'') 来评估岩石和土体的物理、化学和水文地质性质。目前, 泥炭土的电导率 (σ' 和 σ'') 与其物理性质之间的关系还不明确。本文改进了固结仪使其能进行电导率测量, 针对原状样和重塑样开展了系列试验。试验结果表明, 纤维泥炭土微观结构上的各向异性导致了其水-力和电导率呈现出各向异性。在固结过程中, 泥炭土的结构不断演化, 各向异性程度逐渐降低, 伴随着 σ' 的降低, σ'' 则没有受到显著影响。 σ' 和 σ'' 都随着孔隙流体电导率 σ_w 的增加而显著增加, 且近似于 σ_w 的幂指数关系。

关键词: 电导率; 土体结构; 各向异性; 孔隙流体电导率

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