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POTENTIAL OF ELECTRIC AND ELECTROMAGNETIC SIGNAL FOR HYDRIC STATE DIAGNOSIS OF BUILDING STRUCTURES. CASE OF 2 INNOVATIVE TECHNIQS.

A-L. Perrier ⁽¹⁾, N. Prime ⁽¹⁾, A. Revil ⁽²⁾, C. Bermond ⁽³⁾

⁽¹⁾ LOCIE, Université Savoie Mont Blanc, CNRS UMR 5271, Le Bourget-du-Lac, France ⁽²⁾ EDYTEM, Université Grenoble Alpes, Université Savoie Mont Blanc, CNRS UMR 5204, Le Bourget-du-Lac, France ⁽³⁾ CROMA, Université Grenoble Alpes, Université Savoie Mont Blanc, CNRS UMR 5130, Grenoble, France

Context

Raw earth = **environmentally friendly** building materials
BUT **sensitive to water** (weakening of the mechanical capacity)

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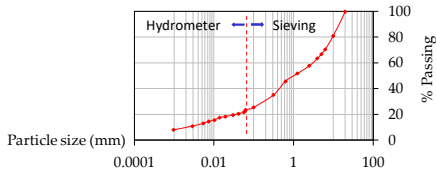
Objectives

High necessity to diagnose water content
 $w(\%) = m_w/m_s$

Non-localized and non-destructive measurement methods based on :
- Sinusoidal **electrical investigation** (induced polarization)
- Sinusoidal **electromagnetic investigation** (free-space radiofrequency)

Earth sample and drying conditions

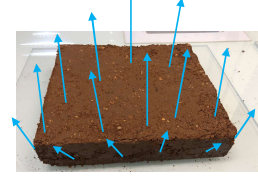
Earth from Orangerie building (Lyon)



Dynamical compaction in layers (like rammed earth)
2 samples in drying :

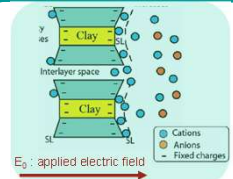


Earth prism
2 cm sieved
 $\rho_d = 18,4 \text{ kN/m}^3$
 $15 \times 15 \times 45 \text{ cm}^3$
1D drying

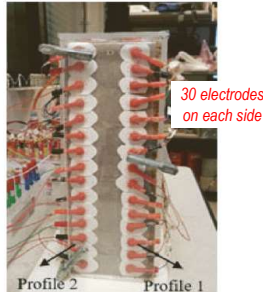
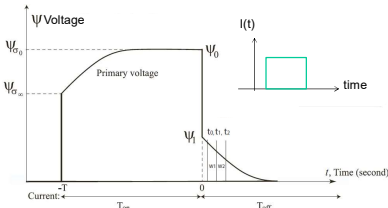


Earth plaque
1 cm sieved
 $\rho_d = 17,8 \text{ kN/m}^3$
 $30 \times 30 \times 6 \text{ cm}^3$
3D drying

1. Induced polarization



Principle of the measure :
Electric current injection and measurement of **resistive and capacitive properties** of soils (electric relaxation).



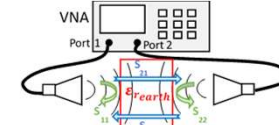
→ Polarization of clay particles surface in DC

2. Free-space radiofrequency

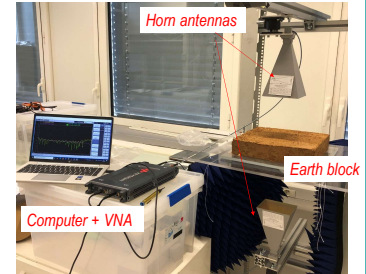
Principle of the measure :
Electromagnetic signal injection and measurement of the **attenuation and phase lag** of an electromagnetic signal

VNA + 2 horn antennas
TRL calibration

S parameters measurement



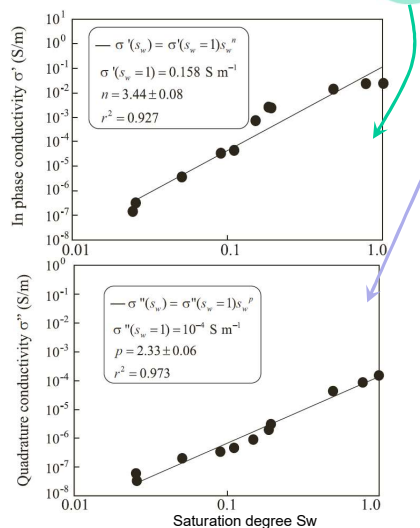
S_{11} and S_{22} : reflection coefficients
 S_{21} and S_{12} : transmission coefficients



Compromise between sample size and frequency : => **8-14 GHz**

→ Results in AC with 1 Hz :

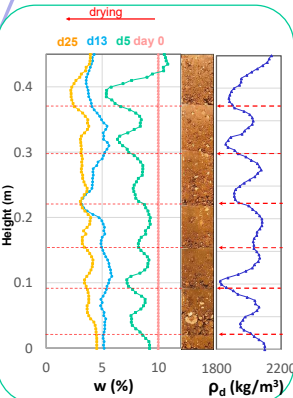
Conductivity = complex function : $\sigma^* = \sigma'(\omega) + i\sigma''(\omega)$



Dynamic Stern layer model links σ^* with CEC, Sw

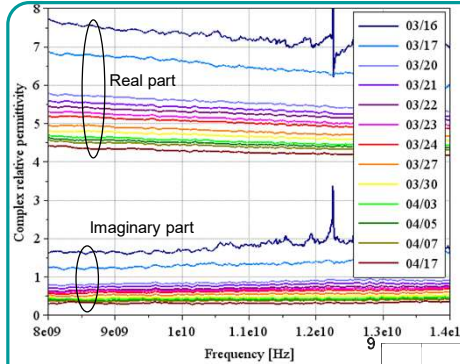
[1] Revil A., et al. Geophysics, (2013) 78(4), D271-D291
[2] Revil A. et al., Water resour. Res. (2017), 53(8), 7121-7147

In phase conductivity: linked to bulk water
Quadrature conductivity: linked to CEC, w, porosity ϕ



$$M_n \equiv \sigma_\infty - \sigma_0 = \frac{S_w^p}{F\phi} \rho_d \lambda \text{ CEC}$$

$$\sigma_\infty = \frac{S_w^n}{F} \sigma_w + \left(\frac{S_w^{n-1}}{F\phi} \right) \rho_d B \text{ CEC}$$

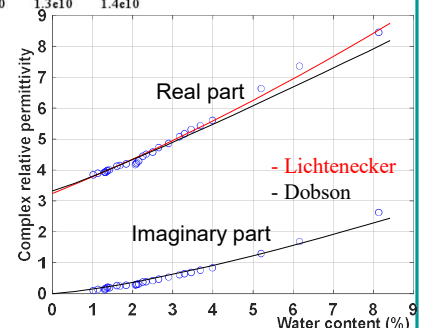


Good agreement with empirical models in the literature:

- Lichteneneker model [3]
- Dobson model [4]

Measurements :

- Throughout the drying process :
- weighing
- 4 S parameters => Complex permittivity extraction using Ross-Nicholson-Weir method



[3] T. Zakri et al., J. Phys. D: Appl. Phys. 31 (1998) 1589-1594

[4] M. C. Dobson et al., IEEE Trans. Geoscience and remote sensing, vol. ge-23, no. 1, 1985.

3. Conclusion

These 2 methods are promising with -for each- its specificities :

Detection of high water content : >2
Here 60 electrodes installed on the sample, Time of acquisition : ~1h
Low frequency 1mHz - 10kHz
3D reconstruction possible of w
A data of w is required on a given point

Detection of low water content : ~1h
Non-contact measurement, instantaneous
High frequency : 8-14 GHz
1 average value for w
A media calibration curve is required