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MOisture detection in historic MAsonry

Does electro-osmosis work in moisture damage prevention? Applicability of infrared-based methods to verify water distribution under electric fields

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UNIVERSITÀ DEGLI STUDI DI MILANO

Does electro-osmosis work in moisture damage prevention? Applicability of infrared-based methods to verify water distribution under electric fields

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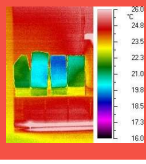
Contents

- Many degradation phenomena are driven by the presence of water
- The electro-osmotic treatments effectiveness is controversial
- Noninvasive and quantitative evaluation of moisture content is the core problem in the study of the effectiveness of dehumidification processes against rising damp

Introduction

Materials

Discussion



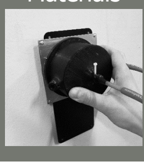
Conclusion

Introduction

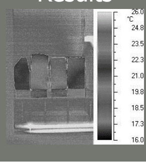
- Experimental evaluation of an optical reflectance (NIR) system suitable to quantify the moisture content of porous media
- Drying behaviour of building specimens with and without the application of the electric fields

Introduction

Materials



Results



Conclusion

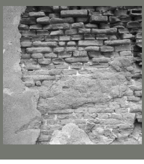
What is electro-osmosis?

- Active electro-osmotic dehumidification systems are based on the electrokinetic effects, caused by the application of a direct current in a saturated porous system and the resulting water migration processes inside pores and capillaries.
- In brief, ions with a charge opposite to that of the solid system are attracted by the solid surface and their concentration would be grater in proximity of the liquid-solid interface.
- Aims of electro-osmosis is to oppose the natural streaming potential inside the capillaries of masonries. Ions with the same surface charge arranges consequently far from the solid surface until a steady state condition is reached.
- Usually inside the wall is installed the positive pole and in the ground the negative pole. Under the application of an external electric field the ions accumulated in the electrical double-layer tend to restore the electro-neutrality of the system, moving towards the negative electrode.
- The resulting transport of water is related to the intensity of the voltage gradient, to the properties of porous material and to the chemical composition of the water solution itself

Materials and methods

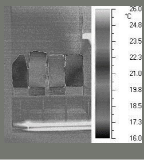
- Laboratory specimens
- Infrared-based monitoring methods (NIR spectrometry and Thermography) compared with gravimetry

Introduction



Materials

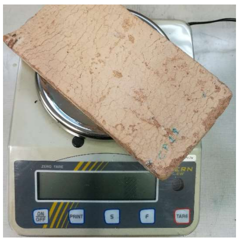
Results



Conclusion

Methods: Gravimetric moisture content

- UNI NORMAL 40/93
- Kern EW 1500-2M balance with an accuracy of 0.01 g



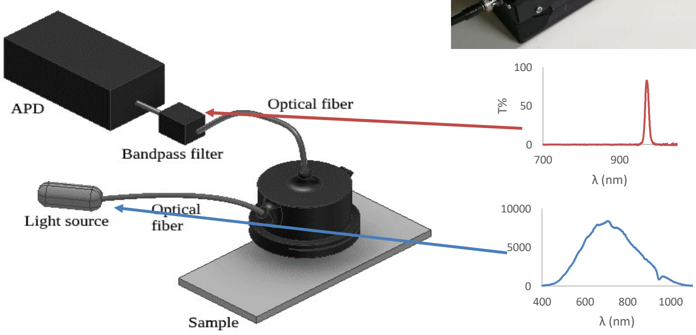
$$MC = \frac{m_w}{m_d}100 = \frac{m_x - m_d}{m_d}100$$

$$SG = \frac{m_x - m_d}{m_{sat} - m_d}100$$

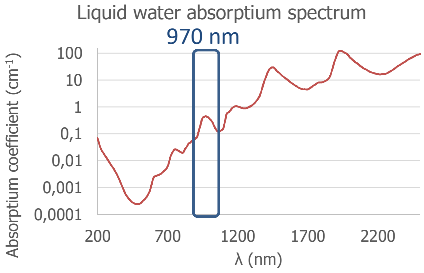
m_w = quantity water mass inside the specimen
m_d = dry weight of the sample
m_x = weight of the specimen at different MC
Msat = saturated weight of the specimen

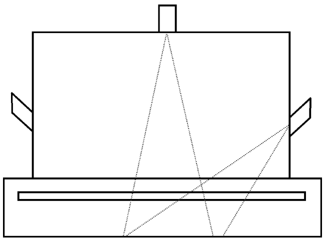
Methods: APD

- Thermo-electrically cooled Avalanche Photodiode operating in Geiger mode
- Multi-pixel photon counting (MPPC) module by Hamamatsu Photonics K.K., model C11208
- Operating temperature: -19° C
- Spectral Range 400-1000 nm



APD - 2





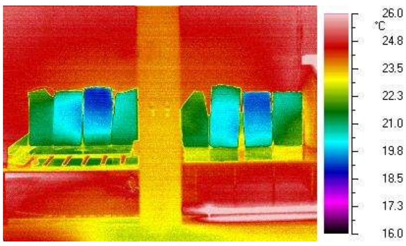
- Spectral reflectance factor (R%) acquisition geometry: 45°x:0°
- Measured spot of about 7 cm^2
- 30 counts for each MC value on the top and on the bottom of the specimens

$$R\% = \frac{\Phi_{\uparrow,specimen,\lambda}}{\Phi_{\uparrow,ideal\,diffuser,\lambda}}100 = \frac{C_m - C_d}{C_w - C_d}100$$

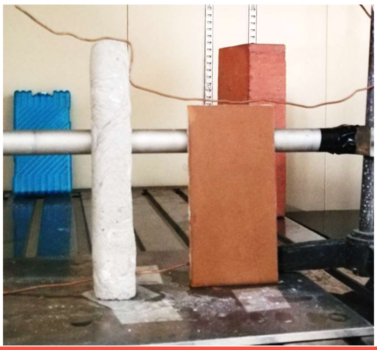
C_m = photons counted by the detector at different moisture content
C_d = dark counts
C_w = counts on the ideal diffuser

Infrared Theromgraphy

- AVIO TVS-700 microbolometer long-wave thermocamera
- It measure the surface temperature of objects and represent it as false colour images
- High sensitivity to evaporation flux from damped materials due to very high water latent heat of evaporation
- Passive approach



Trial 1				
Specimen	Dimensions (cm)	Dry density (g/cm^3)	Saturated density (g/cm^3)	MC at saturation (%)
T1 Ceramic tile	15.4x7.2x0.7	2.62	2.72	3.96
T2 Ceramic tile	15.4x7.2x0.7	2.64	2.76	4.69
P1 Cement plaster	23.3x3x1.6	1.46	1.79	22.72
P2 Cement plaster	19.5x3.3x1.9	1.41	1.74	22.82



Trial 1

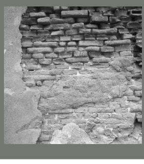
Trial 2				
Specimen	Dimensions (cm)	Dry density (g/cm^3)	Saturated density (g/cm^3)	MC at saturation (%)
LT1 Brick	18.7x 9.2x2	1.66	1.90	14.39
LT2 Brick	18.3x8.5x2	1.75	2.01	14.41
MA1 Lime mortar	16.4x10.4x2.4	1.41	1.66	17.88
MA2 Lime mortar	19.2x10.5x2.4	1.41	1.65	16.55
MC1 Cement mortar	19.7x8.8x2.3	1.60	1.99	24.57
MC2 Cement mortar	18.2x9.1x2.3	1.62	2.01	24.64
CP1 "Cocciopesto"	19.9x9.8x1.8	1.62	1.93	19.13
CP2 "Cocciopesto"	20.5x10.7x1.8	1.44	1.73	20.20

Trial 2

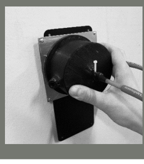
Results

- Trial 1: Drying behavior with and without the application of ΔV
- Trial 2: Drying behavior with and without the application of ΔV
- Trial 3: Application of different ΔV values on saturated specimens in euilibrium condition

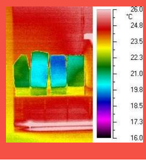
Introduction



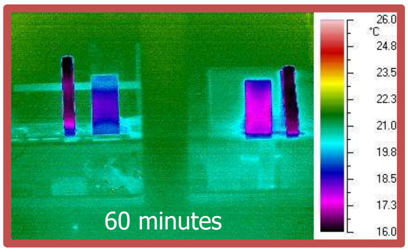
Materials

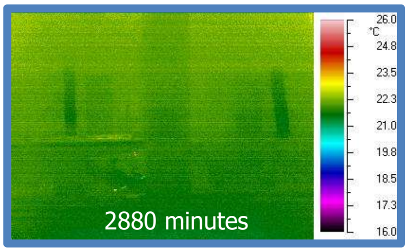


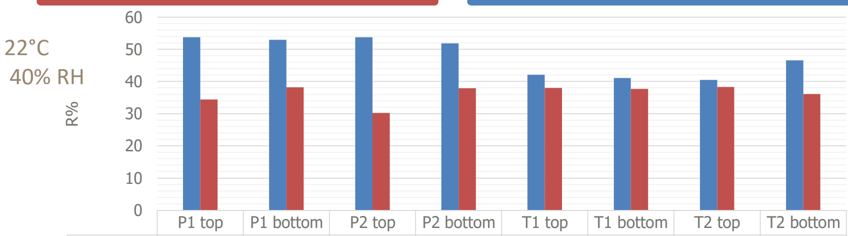
Results



Conclusion

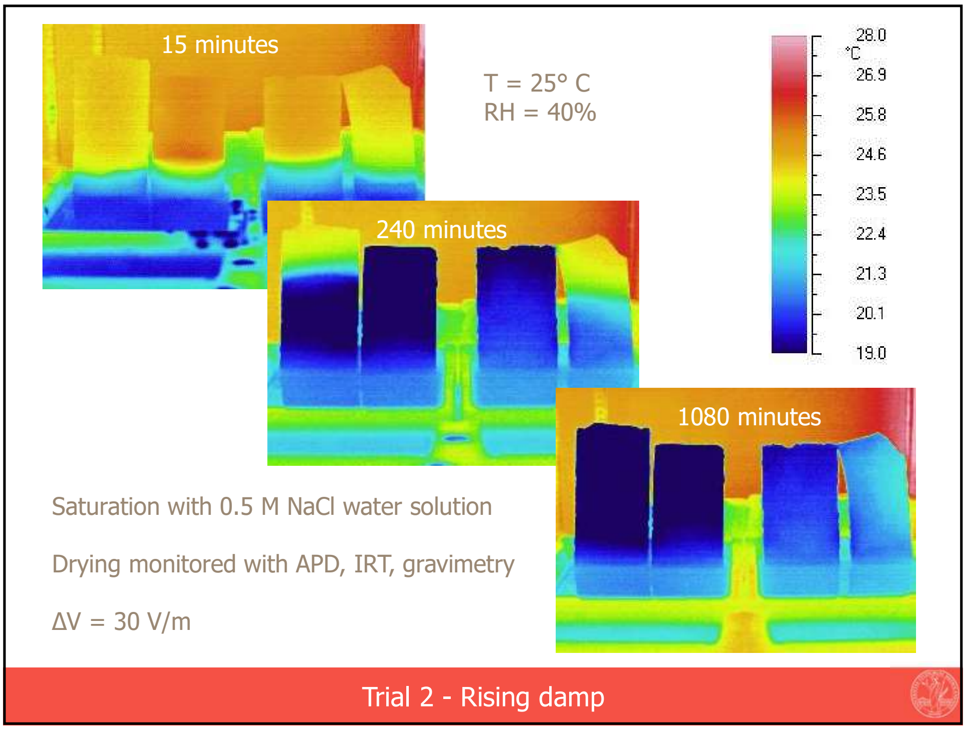


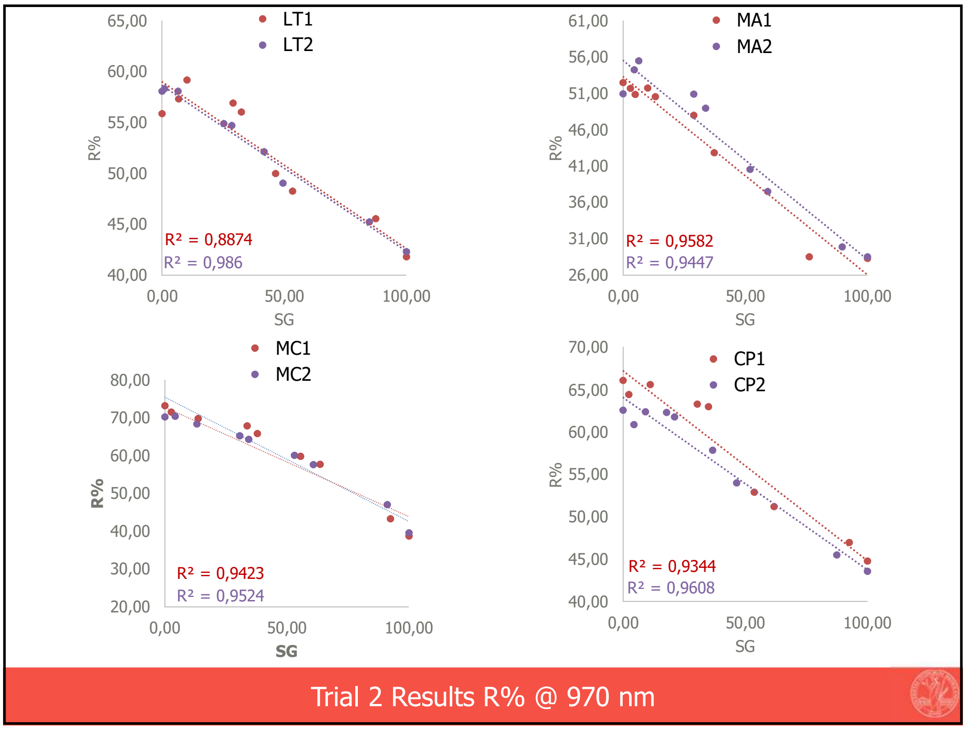


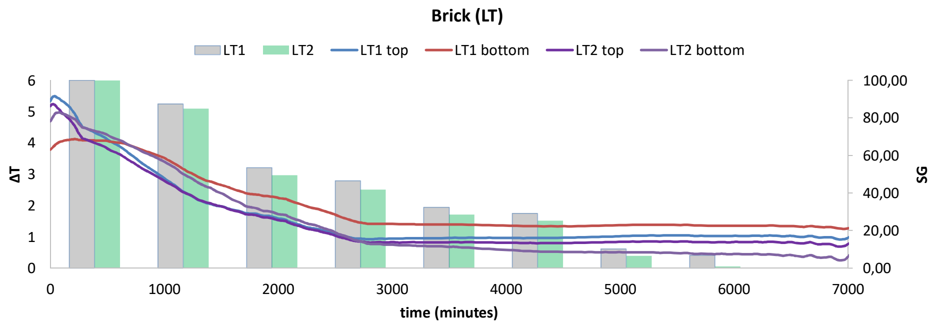


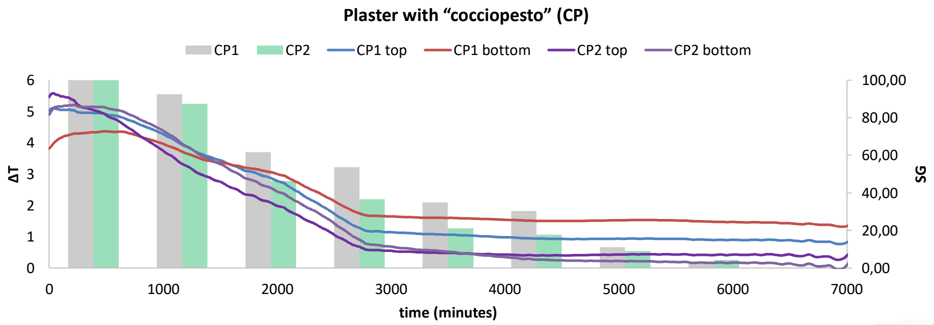
	P1 top	P1 bottom	P2 top	P2 bottom	T1 top	T1 bottom	T2 top	T2 bottom
Dry	53,71	52,98	53,71	51,82	42,12	41,13	40,48	46,59
Saturated	34,38	38,16	30,26	37,88	38,03	37,72	38,31	36,08

Trial 1

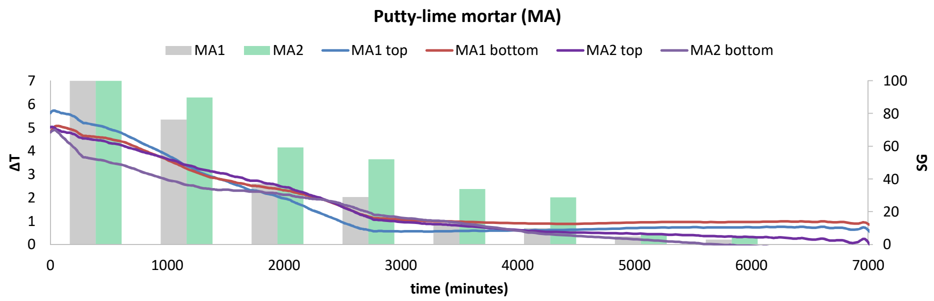

15 minutes
240 minutes
1080 minutes
T = 25° C
RH = 40%
28.0
°C
26.9
25.8
24.6
23.5
22.4
21.3
20.1
19.0
Saturation with 0.5 M NaCl water solution
Drying monitored with APD, IRT, gravimetry
ΔV = 30 V/m
Trial 2 - Rising damp

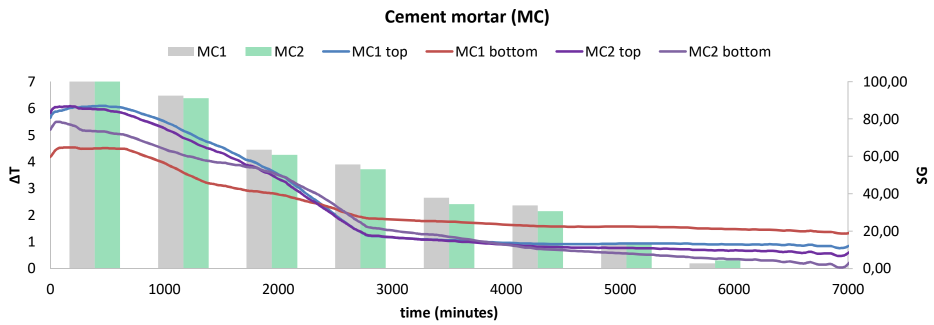

LT1
LT2
R%
SG
R² = 0,8874
R² = 0,986
MA1
MA2
R² = 0,9582
R² = 0,9447
MC1
MC2
R² = 0,9423
R² = 0,9524
CP1
CP2
R² = 0,9344
R² = 0,9608
Trial 2 Results R% @ 970 nm



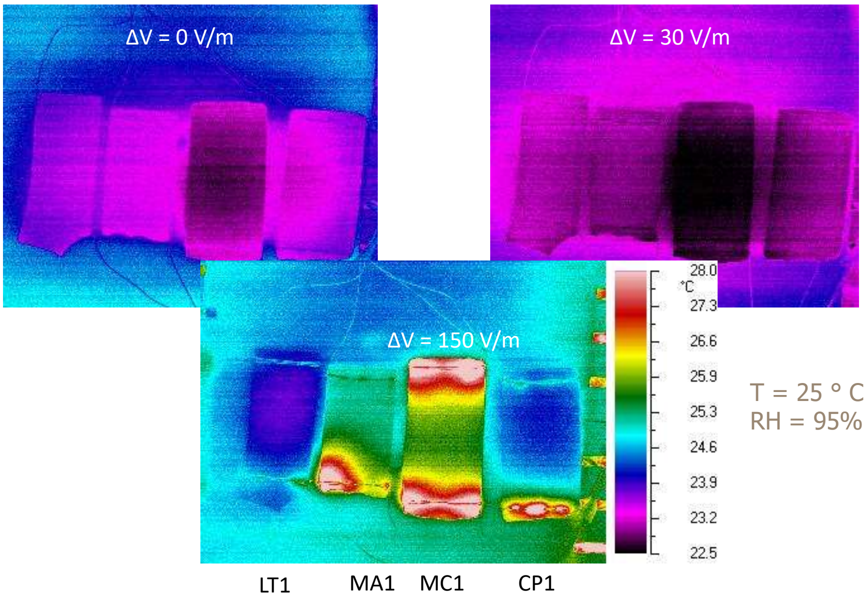


Trial 2 - cooling due to evaporation





Trial 2 - cooling due to evaporation



Trial 3 - Effects of elcetric fields on saturated materials

Conclusions

- Rapid, simple and noninvasive measurement of the MC of porous media based different infrared radiation spectral reflectance factor at 970 nm
- No evident water displacement caused by the application of an electric field
- Joule effect detected with IRT only at high applied ΔV → different ions displacement