Use of Fibre Optic and Electrical Resistance Sensors for Monitoring Moisture Movement in Building Stone Subjected To Simulated Climatic Conditions


*School of Planning Architecture and Civil Engineering, **School of Geography, Archeology and Palaeoecology, Queens University Belfast, ***School of Engineering and Mathematical Sciences, City University London

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Outline of Presentation

- Introduction
  - Salt Weathering
- Monitoring moisture in building stone
  - Electrical resistance sensors
  - Fibre optic relative humidity probe
- Experimental setup
- Results
  - Temperature
  - Electrical resistance (ER)
  - Relative humidity (RH)
- Summary
- Acknowledgements

Salt weathering – Decay sequence

Salt weathering – Controlled by temperature and moisture regimes

Wetting

Rapid temperature changes

Multiple flaking
Moisture measurement methods

- Gravimetric method
  - Core extraction
- Electrical method
  - Resistance/Conductance based
  - Capacitance based
- Microwave method
- Nuclear Magnetic Resonance (NMR)
- Optical method
  - Fibre Optic sensors (FOS)

Electrical resistance sensors

Change in resistance due to
- Moisture movement
- Ions (Chlorides)
- Temperature

Not possible to distinguish between Cl⁻ or other ions

Capillary rise test

\[ d = S \sqrt{\frac{t}{D}} \]

Advantages of FOS in monitoring structures

- Small and light weight
- Easy to multiplex
- High Sensitivity
- Non destructive long-term monitoring system
- Chemically inert (does not corrode)
- Immune to Electromagnetic interference
- Can transmit Optical signals easily over several miles

Disadvantages

- Careful handling
FBG as Fibre Optic Sensor

Reflectance spectrum

Transmittance spectrum

Temperature/stress/strain/humidity by coating overlay

Transmittance spectrum

λ_B: the Bragg wavelength, is defined by:

\[ \lambda_B = 2nA \]

n: the average refractive index of the grating
A: the grating period.

Humidity probe

PI coated FBG

Temperature sensor

Heat shrink

Porous Filter

Porous ceramic cap

Detachable porous cap

Calibration

Temperature (°C)

Relative Humidity, RH (%)
Experimental setup

- Sample dimension 150X150X80 mm
- ER sensors (0.5cm, 1cm, 2cm & 5cm)
- Temperature sensor (0.5cm, 1cm, 2cm & 5cm)
- FOS-RH sensor (3cm)
- Capacitance based RH sensor (3cm)
- Ambient temp. 20°C; 50% RH
- 30 min ON/ 15 min OFF
- Water spray 20°C/10 min
- With/Without airflow across surface of stone

Experimental regime

Sample preparation
- Limestone block 150X150X80 mm – Stoke ground base bed
- Test block dried at 50°C before each test
- Placed in cabinet and allowed to equilibrate to ambient temperature and simulated conditions in cabinet

Variables examined
- Temperature variation with depth in response to heating and cooling
- Wetting and drying (ER sensors and FOS-RH probe)
- Influence of airflow/wind condition

Results – Temperature profiles

No Airflow at surface of stone

<table>
<thead>
<tr>
<th>Time (hrs)</th>
<th>6.00</th>
<th>6.50</th>
<th>7.00</th>
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<tr>
<th>IR Temp</th>
<th>0.5 cm</th>
<th>1.0 cm</th>
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<td>Dry</td>
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Airflow at surface of stone

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<td>Temperature (°C)</td>
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Results – ER measurement

No Wind

Wind

Results – FOS RH measurement

No Airflow at surface of stone

Airflow at surface of stone

Summary

- Fabricated new FOS–RH probe with porous cap that has obtained reliable results in simulated climatic conditions
- ER sensors provide a relatively inexpensive and reliable means of measuring moisture changes in stone
- Rapid temperature changes at surface creates steep temperature gradients at outer few mm possibly causing fatigue effects
- Airflow at surface substantially influences temperature and moisture regimes in building stone
- The moisture penetration at 30 mm depth of stone continues even upon drying of surface moisture due to airflow and intermittent thermal cycles
Moisture distribution in soils

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