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

Sudarshan Srinivasan*,P.A.Muhammed Basheer*, Bernard J.Smith, Miguel Gomez-Heras**, Ken Grattan*** and Tong Sun*****

***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

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Salt weathering – Decay sequence

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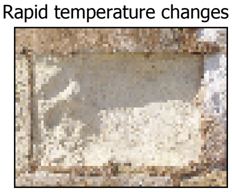
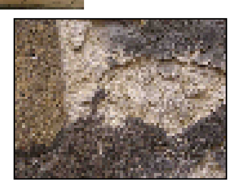
Salt weathering – Controlled by temperature and moisture regimes

Wetting

Rapid temperature changes





Multiple flaking

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Monitoring moisture

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)

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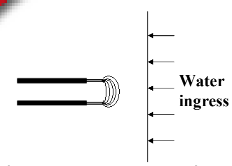
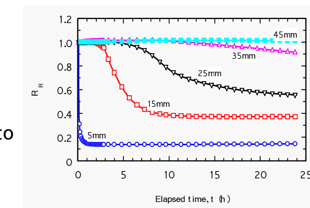
Electrical resistance sensors





Change in resistance due to

- Moisture movement
- Ions (Chlorides)
- Temperature

Not possible to distinguish between Cl^- or other ions

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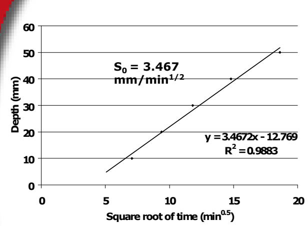
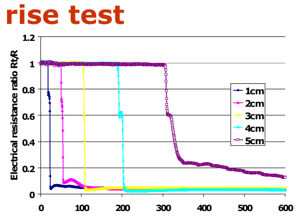
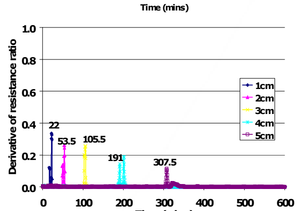
Capillary rise test

$$d = S_o t^{1/2} + d_o$$







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Fibre optic sensors (FOS)

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

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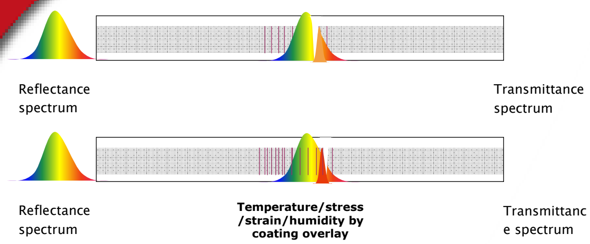
FBG as Fibre Optic Sensor



λB: the Bragg wavelength, is defined by: $\lambda_B = 2n\Lambda$

n: the average refractive index of the grating & **Λ** : the grating period.

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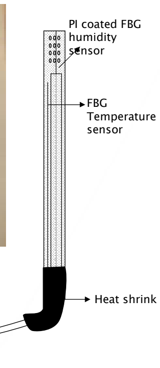
Humidity probe



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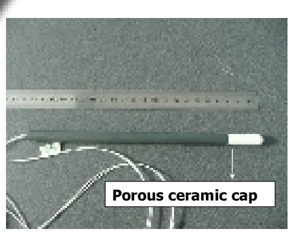
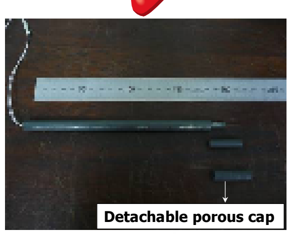
Porous Filter





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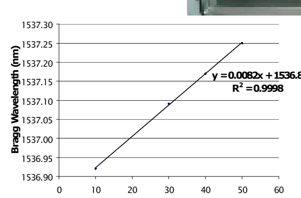
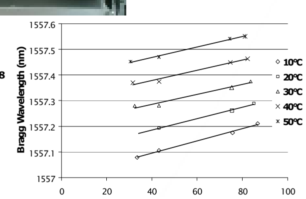
Calibration





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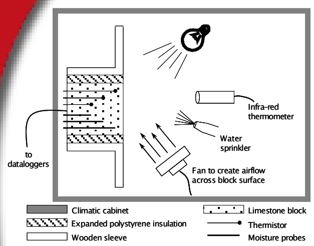
Experimental setup



- 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

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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

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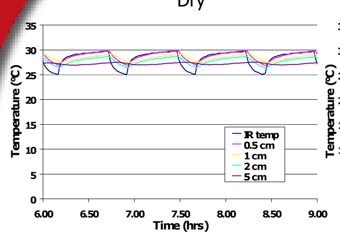
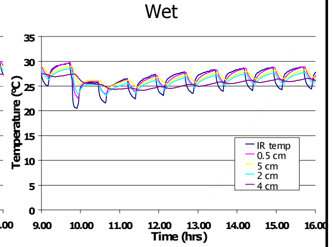
Results – Temperature profiles

No Airflow at surface of stone

Dry



Wet



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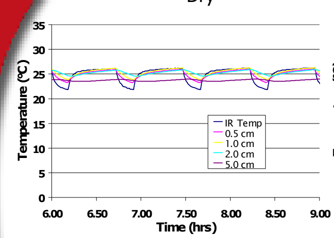
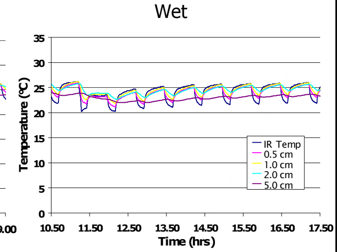
Results – Temperature profiles

Airflow at surface of stone

Dry



Wet



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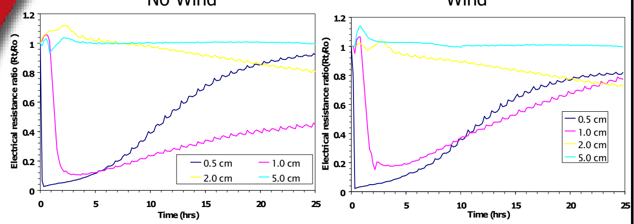
Results – ER measurement

No Wind | Wind



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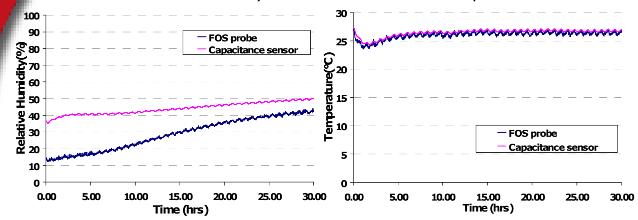
Results – FOS RH measurement

No Airflow at surface of stone

Relative Humidity | Temperature



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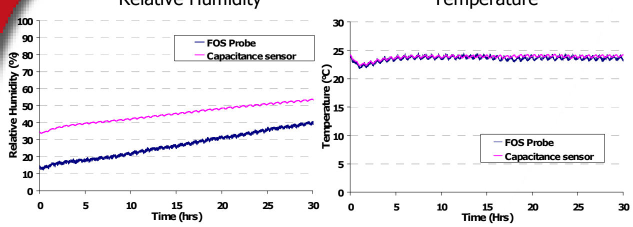
Results – FOS RH measurement

Airflow at surface of stone

Relative Humidity | Temperature



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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

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Moisture distribution in soils

Acknowledgement

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