Characterization of geomorphic pore structure of building materials for agent fate

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Presentation Outline

- Overview/Objectives
- Materials
- Methods and Results
- Conclusions
- Future Work

Research overview

Physical Models

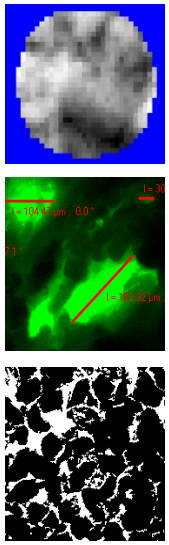
Numerical Models

ANNs

Microscopic Properties

Geomorphic pore structure of substrates:

- Pore size
- Pore shape
- Connectivity
- Surface permeability



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Macroscopic Properties

Surrogate properties

Contact angles

Macroscopic permeability

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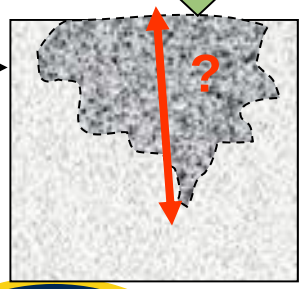


Ensemble Averaging Approach

Overview of Problem

- Characterize pore structure:
  - Fluorescent microscopy
  - X-ray imaging
- Ultimate goal of rapidly predicting agent transport in field cases

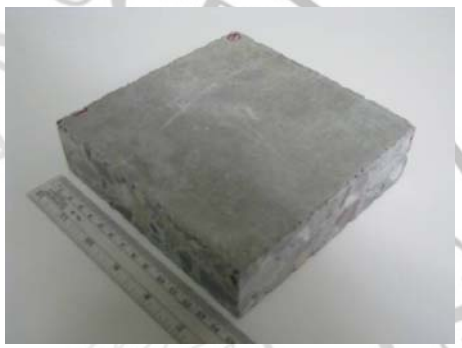
Materials

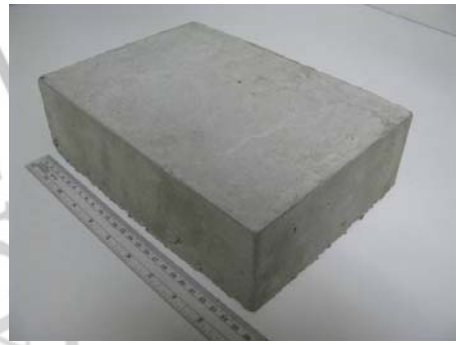
Building materials:

- Ohio sandstone
- Indiana limestone
- Concrete
- Brick

Tests:

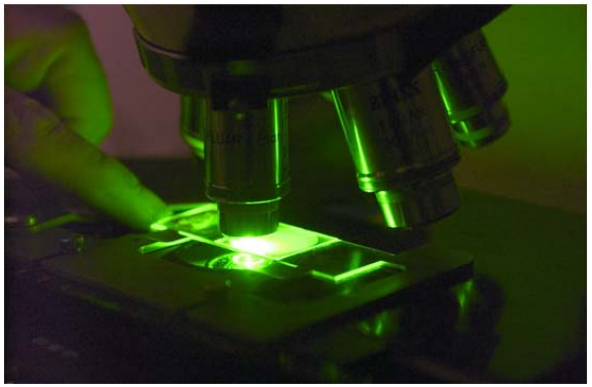
- Fluorescent microscopy
- CT scanning



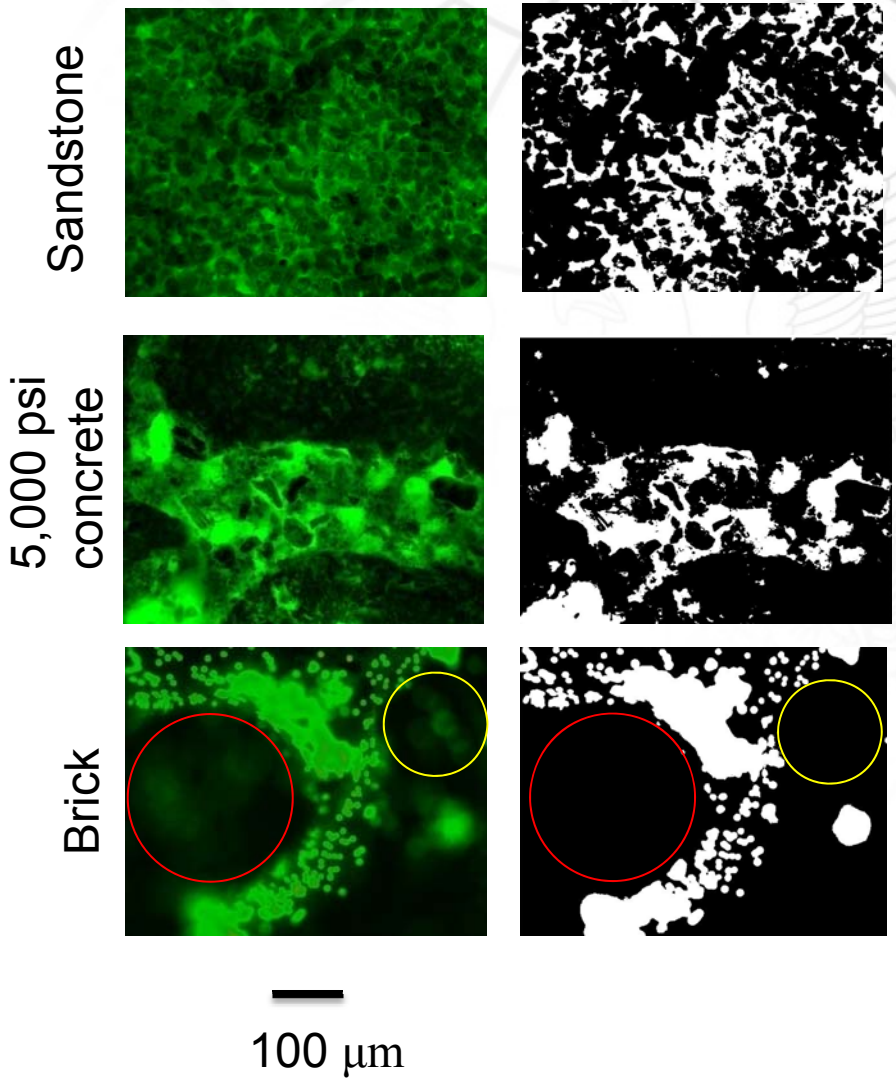


Methods: Fluorescent Microscopy

- Saturate in fluorescent solution (FITC)
- Images provide:
  - Porosity
  - Detailed pore sizes/shapes (stage micrometer)
  - Micro beads for better visualization of pore network



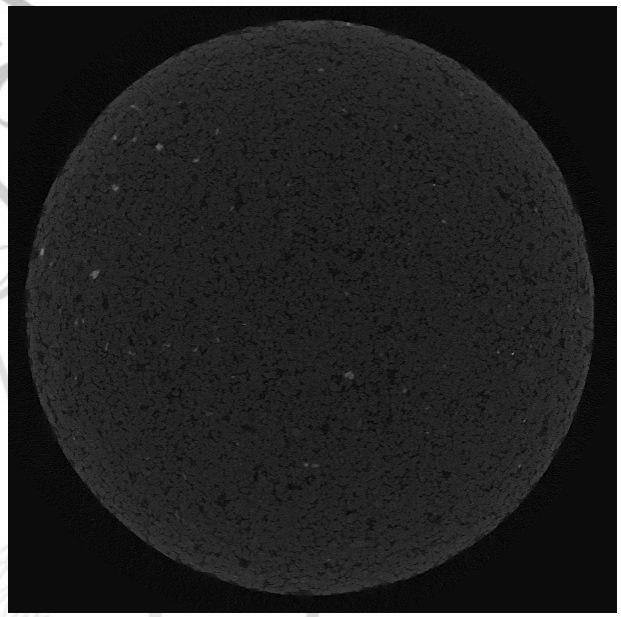
Results: Fluorescent microscopy

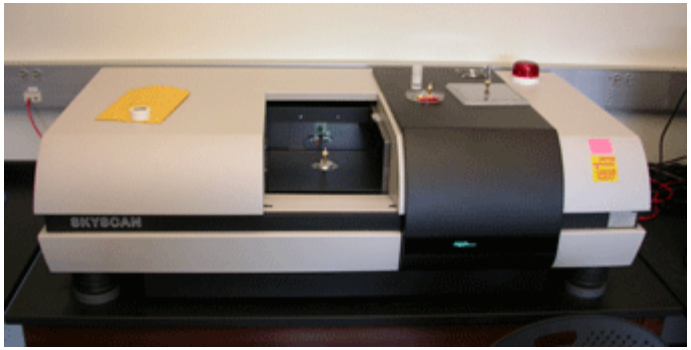


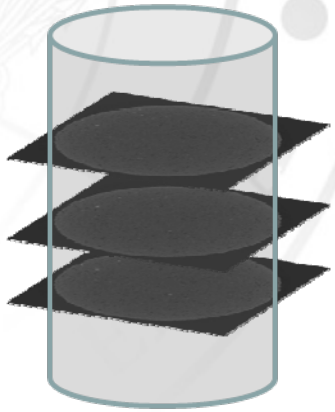
- Relatively Homogeneous
- Heterogeneous

Methods: X-Ray Scanning

- Amherst College, MA
- Resolution: up to 1.5 μm
- Smallest pore 4.5 μm
- Estimate parameters

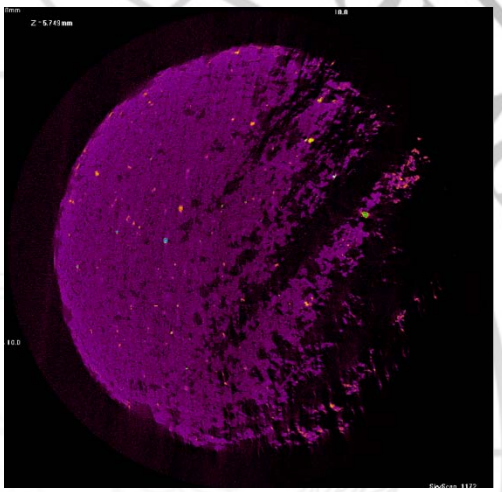


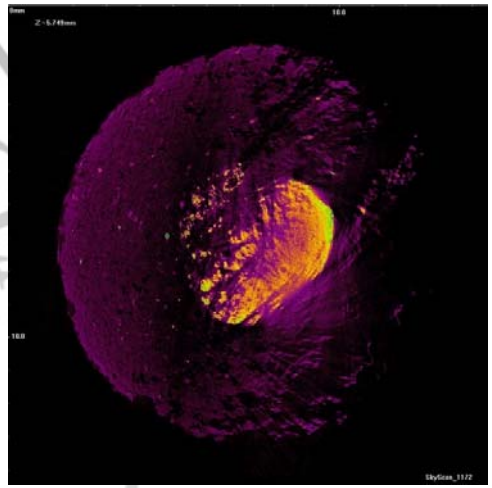


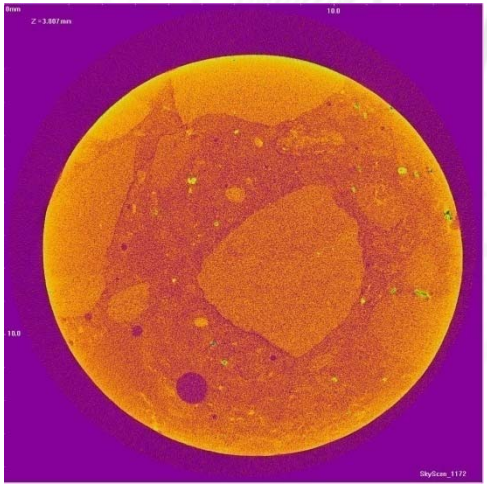


Results: X-Ray Scans

- Addition of fluid
- Transport information per volume of fluid added
- More scans with fluid in process

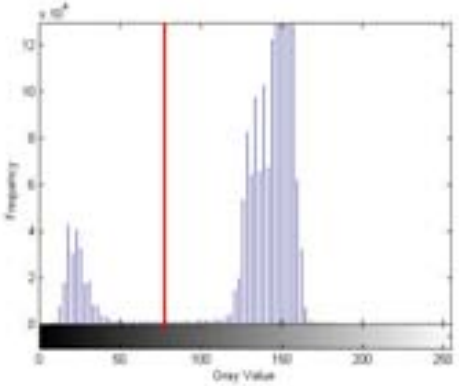


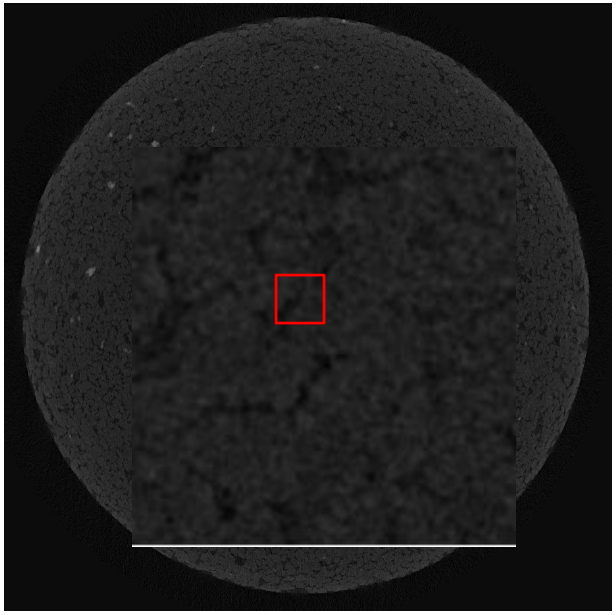


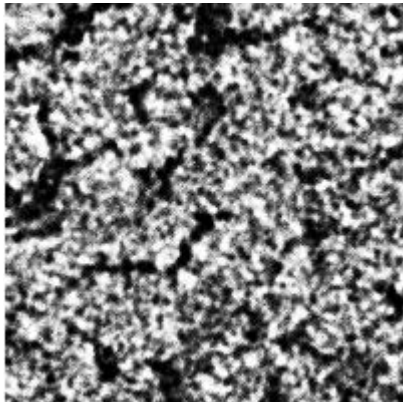


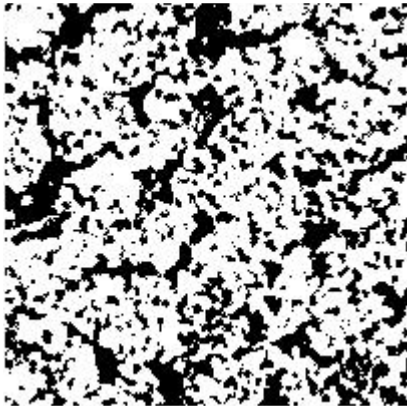
Methods: Image Processing

- 1. Crop original scan
- 2. Contrast enhancement
- 3. Thresholding



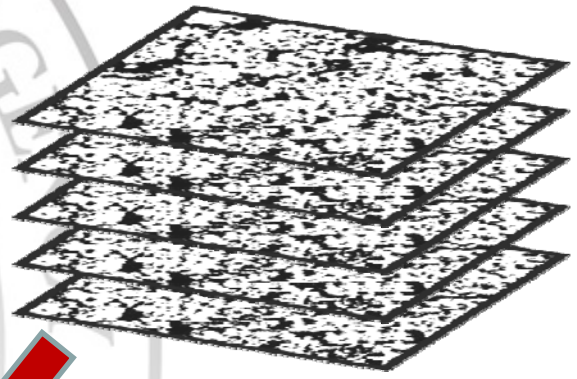






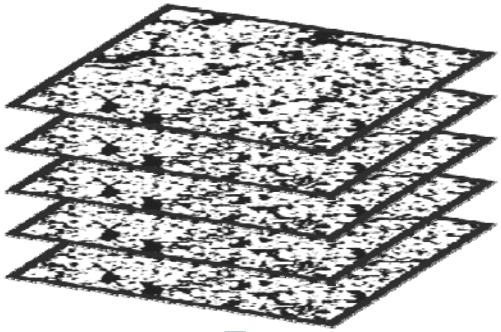
Methods: 3D Reconstruction

- *Avizo 6.0*
- Import/Stack binary images
- 3D surface
  - Material statistics



Results: Pore Surface Generation

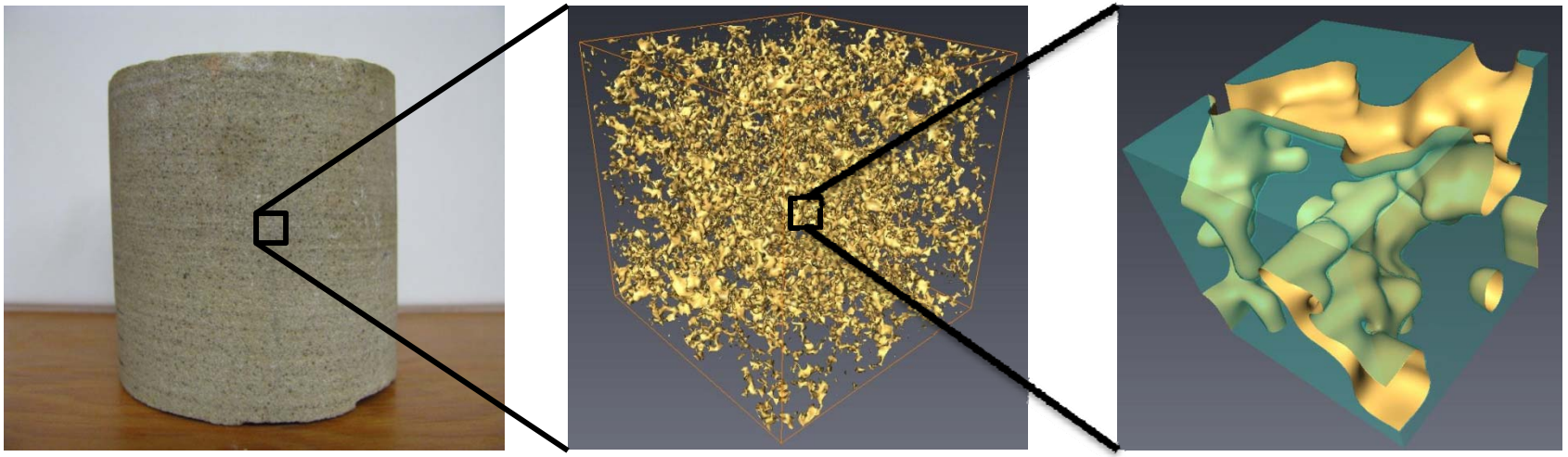
Ohio sandstone



Total porosity = 16%

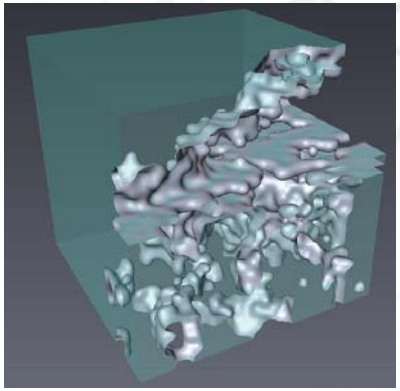
300x300x300 μm

35x35x35 μm

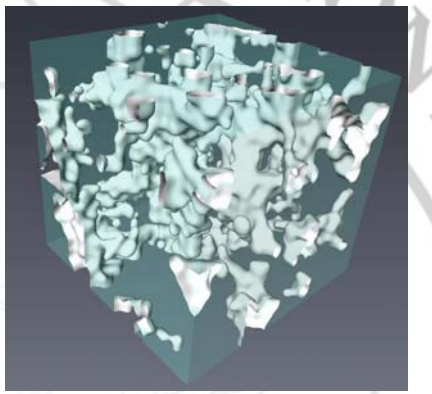


Pore surfaces

5,000 psi concrete

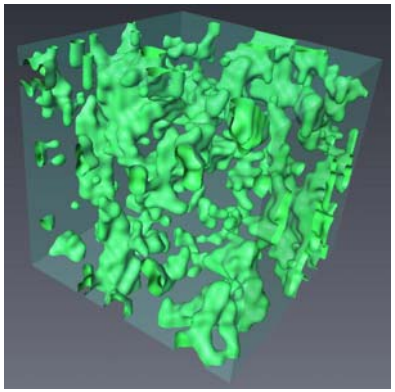


Limestone

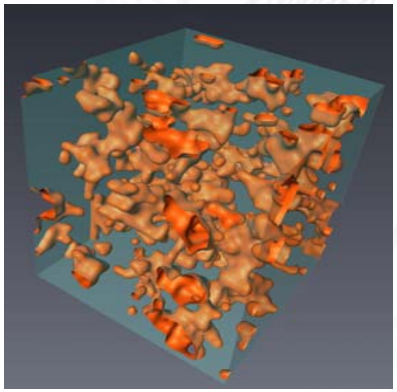


All specimens 100x100x100 µm

D04 concrete



Brick



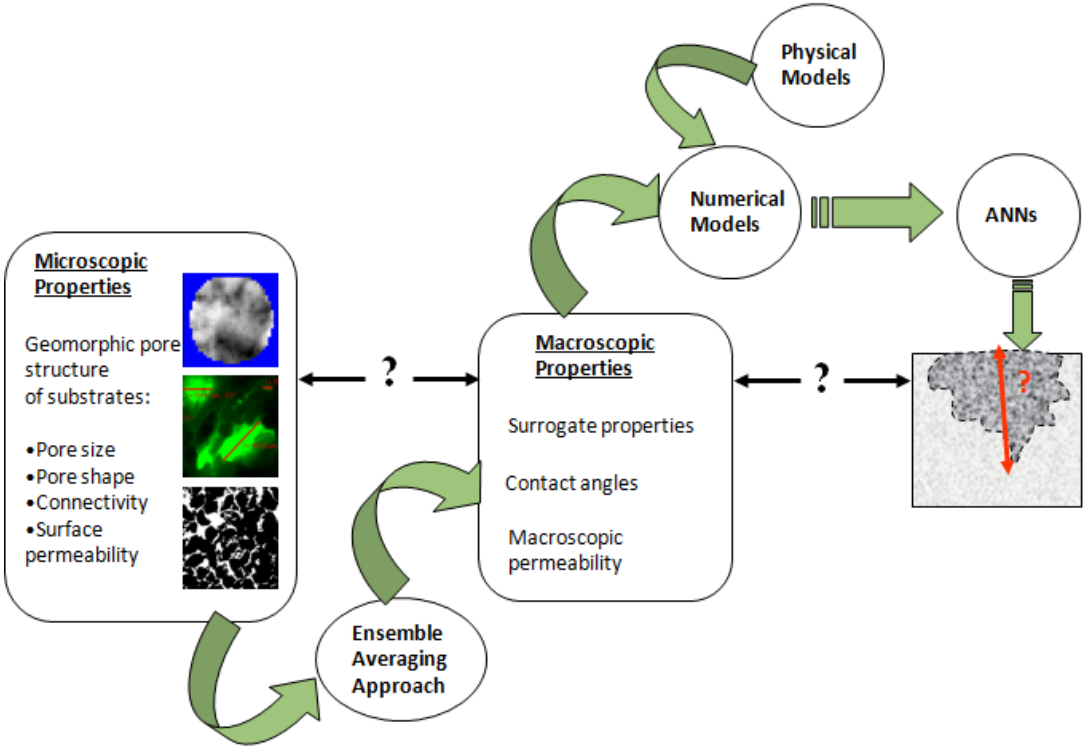
Testing Results

Porosity

	Lab	CT	3D
5,000 psi Concrete	0.12	0.16	0.16
D04 Concrete	0.10	0.14	0.13
Indiana Limestone	0.10	0.13	0.15
Ohio Sandstone	0.16	0.14	0.16
Brick	0.17	0.20	0.18

Conclusions and Future Work

Fluorescent microscopy and X-ray imaging successfully quantified details of pore structure

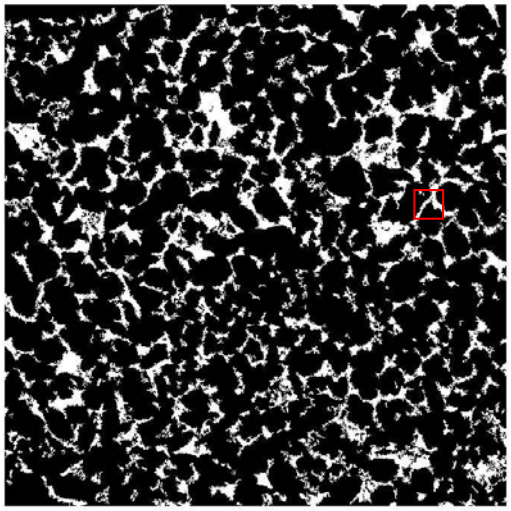


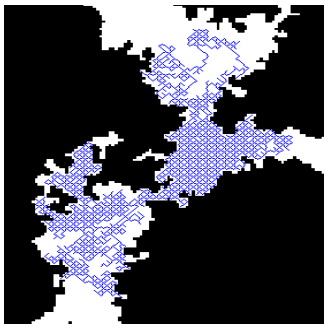
Advanced X-ray image analysis

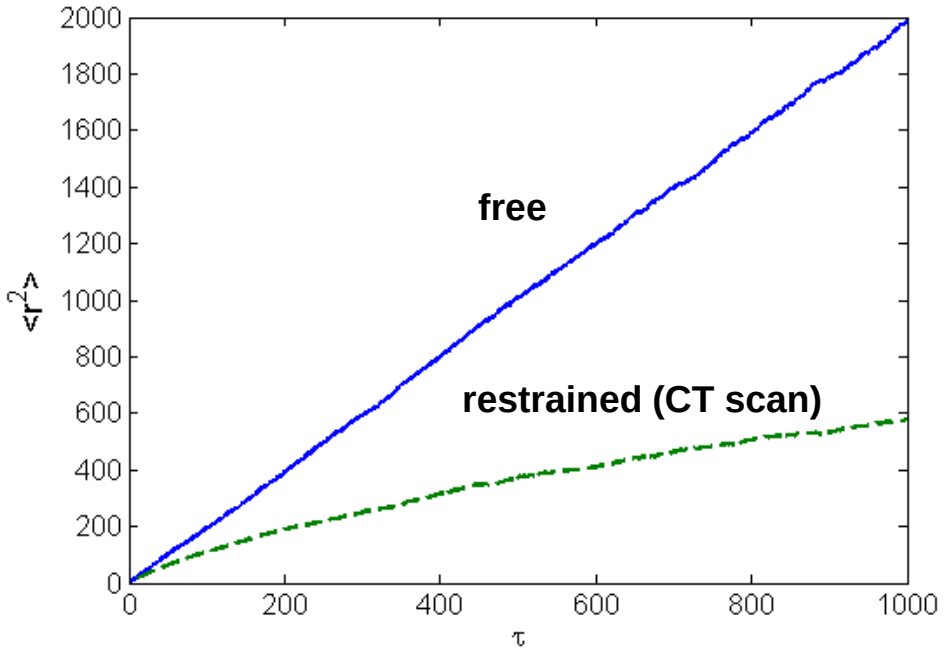
Estimate of transport properties by image analysis (random walk)

- Porosity
- Tortuosity
- Specific surface
- Diffusivity
- Permeability

$$\left\langle r(\tau)^2 \right\rangle = \frac{1}{n} \sum_{i=1}^{n} r_i(\tau)^2$$







Ohio Sandstone

X-rays – continued

Comparison to measurements

	Sandstone	Brick	D04 Concrete	5000psi Concrete
Porosity	**0.15** (0.16)	**0.19** (0.17)	**0.11** (0.10)	**0.13** (0.12)
Specific surface [1/m]	**7E+5**	**8.8E+5**	**1.8E+5**	**1.8E+5**
Tortuosity	**4.4**	**8.9**	**20**	**16.0**
Permeability [m^2]	**7E-14** (15E-14)	**2.7E-14** (4.2E-14)	**16.0E-14** (7.7E-14)	**26.0E-14** (7.9E-14)

Acknowledgements

Prof. Whitey Hagadorn (Amherst College)

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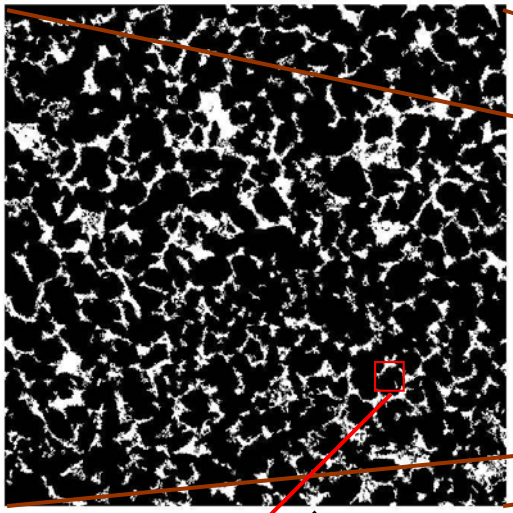
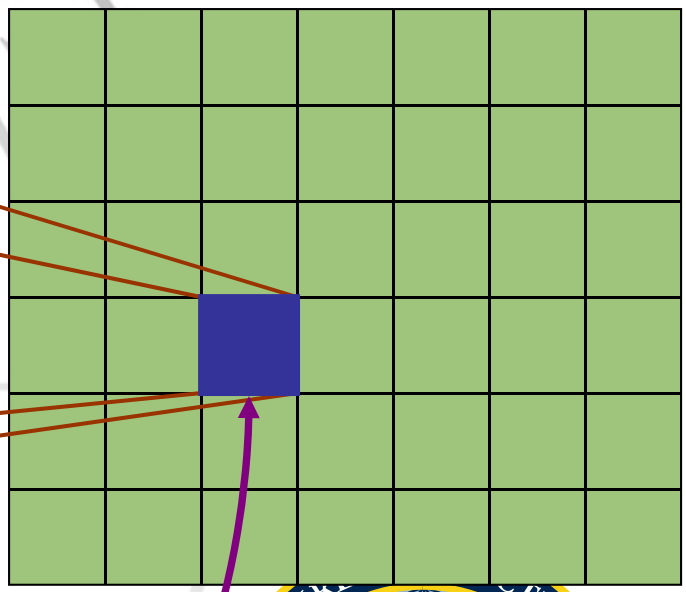
Thank You

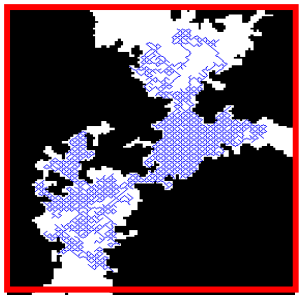
Image → Grid (simulation)

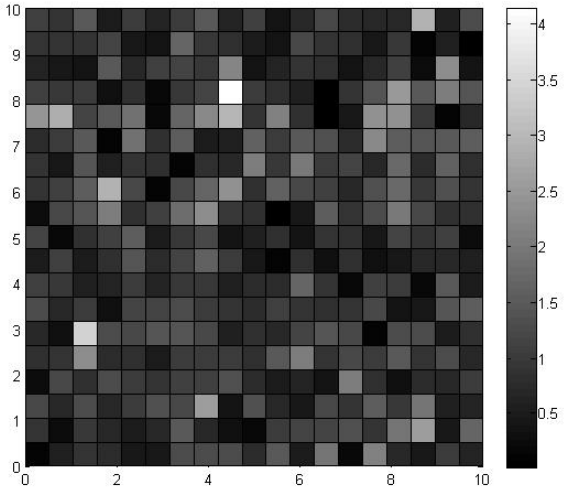
10mm×10mm

70mm×60mm









Simulation of Wicking Tests

Brick