Accurate measurement of radius evolution as a function of direction in 3D images

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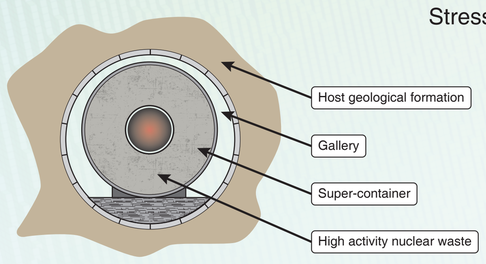
Context

Deep geological nuclear waste storage

Candidate site in Belgium: the Boom region (fitting name!)

Host rock formation: Boom clay (low permeability)

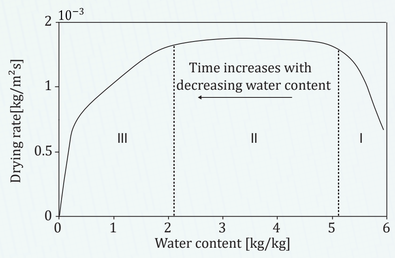
Stress response of clay to heat and dessication



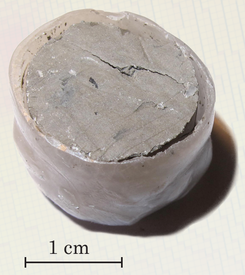
Development of thermo-hydro-mechanical model

Anisotropic deformation (stratified material)

Validation with X-ray microtomography



Materials and methods



Excavated 220m underground,

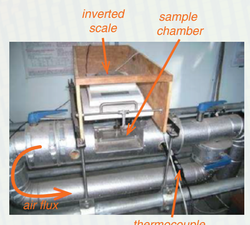
borehole “2007-3/Connecting Gallery/Ring 66-67E/Intrados”

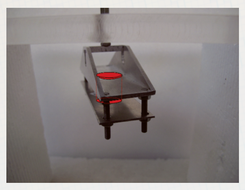
Drilled in ~2cm cylindrical samples (3 sets of 5, 10 and 15mm high)

Coated with paraffin except on top

Custom-made convective dryer

0.8 m/s air flux, 25 °C, 3.5% relative humidity





Drying vessels attached to a scale

Continuous weight measurements

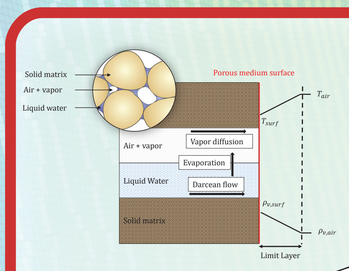
Regular “short” interruptions for XRCT

257 projections at 316 ms exposure time

100 kV, Al filter, 32 µm/pixel



Skyscan 1172

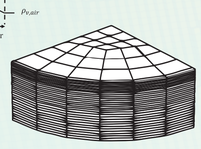


Heat flux :

$$q_h = Lq_w - \beta(T_{air} - T_{surf})$$

Water flux :

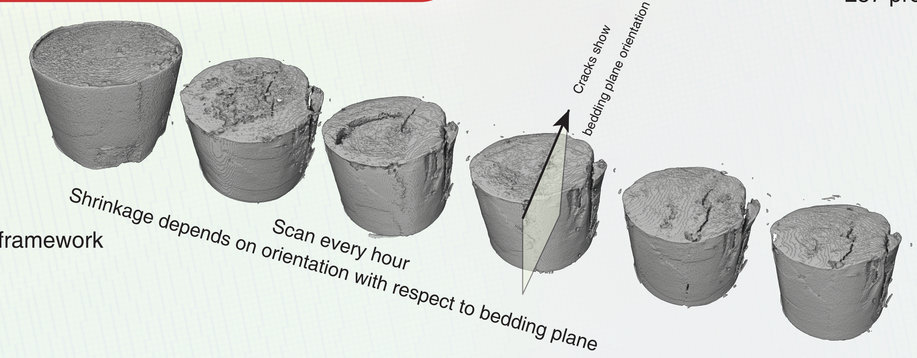
$$q_w = \alpha(\rho_{v,surf} - \rho_{v,air})$$

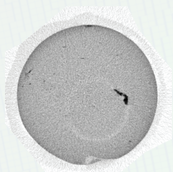


Limit layer model in a FEM framework

Virtual environment node

Boundary conditions:...





Saturated

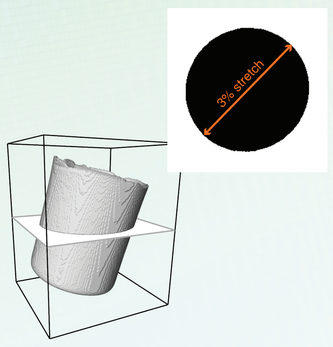


Dry

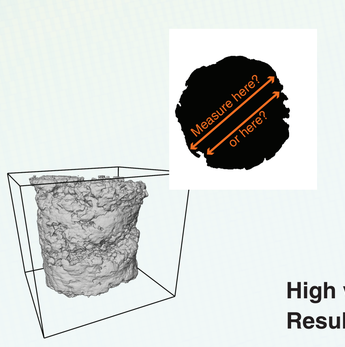
More shrinkage perpendiular to cracks

How much more ?

Manual 2D measurements



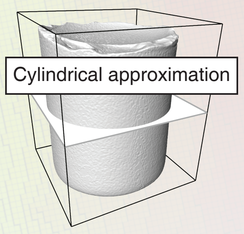
Tilt

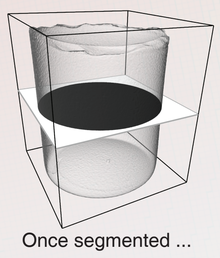


Surface roughness

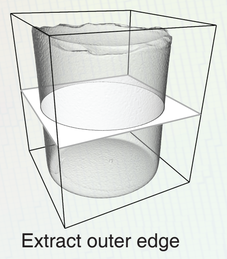
High variability
Results inconclusive

Automatic 3D measurement

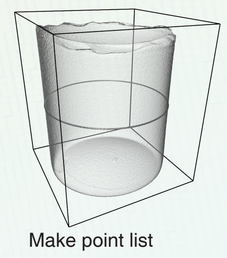




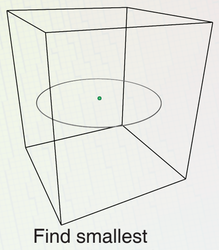
Once segmented ...



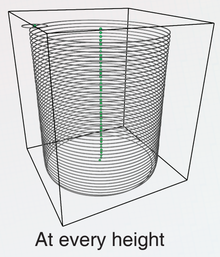
Extract outer edge



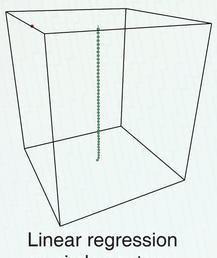
Make point list



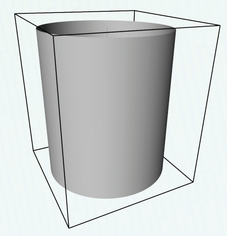
Find smallest enclosing circle ...



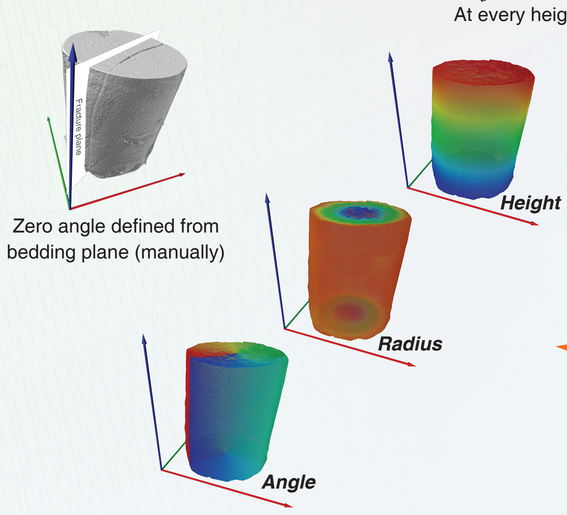
At every height



Linear regression on circle centers ...

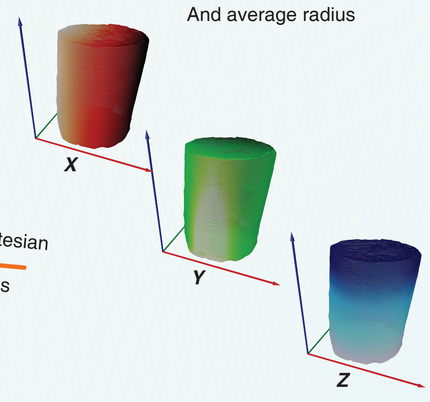


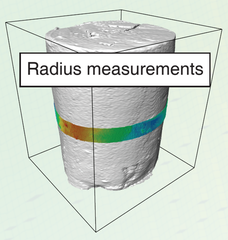
And average radius

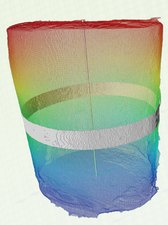


Zero angle defined from bedding plane (manually)

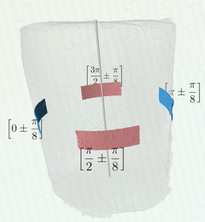
Outer edge points from Cartesian to cylindrical coordinates







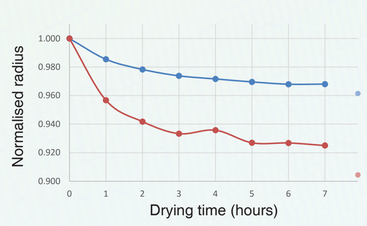
Take points in mid-height area



Take angular wedges around parallel and perpendicular directions

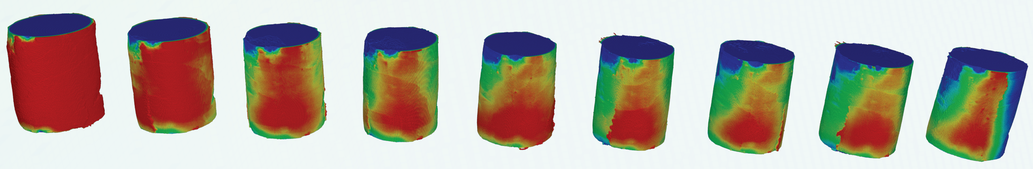


Find average radius in both sets



Average shrinkage after complete drying: 4% and 8% (±1%)

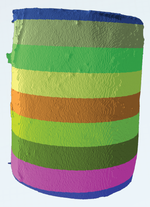
Model predictions: 4% and 8%



Perspectives

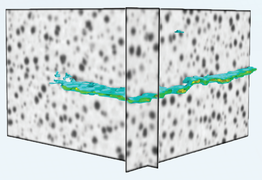
Sliding window along height

Automatic bedding plane localization?



Crack detection

Use of Digital Volume Correlation?



Example of YADIC software

Acknowledgements

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“Experimental and numerical study of cracking during the drying of porous materials”