HAL
open science

Chemical degradation of a numerical material - Application to a Fontainbleau sandstone

Kajetan Wojtacki, Loïc Daridon, Yann Monerie

To cite this version:

Kajetan Wojtacki, Loïc Daridon, Yann Monerie. Chemical degradation of a numerical material - Application to a Fontainbleau sandstone. InterPore - 8th International Conference on Porous Media & Annual Meeting, May 2016, Cincinnati, United States. . hal-01511167

HAL Id: hal-01511167

https://hal.science/hal-01511167v1

Submitted on 20 Apr 2017

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

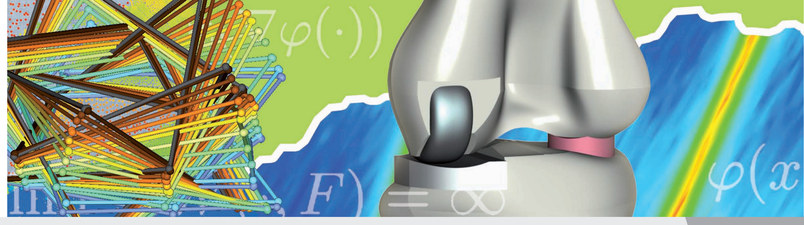
Public Domain

CHEMICAL DEGRADATION OF A NUMERICALLY GENERATED MATERIAL - APPLICATION FOR FONTAINEBLEAU SANDSTONE

K. Wojtacki[1,*], L. Daridon[1,2], Y. Monerie[1,2]

[1] Laboratoire de Mécanique et Génie Civil (LMGC), CNRS UMR 5508, Montpellier, France

[2] Laboratoire de Micromécanique et Intégrité des Structures (MIST), UM, CNRS, IRSN, France



Highlights

1. Simple and efficient method that allows to obtain morphologically equivalent realisations of Fontainebleau sandstone
2. New method allowing to impose periodic B.C. on non-periodic geometries
3. Two simple models of chemical degradation
4. Heuristic relation coupling elastic moduli and permeability

Context

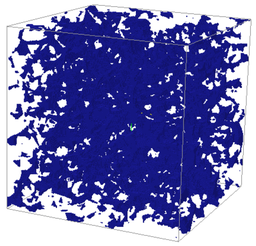
Carbon Capture and Storage (CCS) consists of injecting large quantities of CO_2 in supercritical form directly into deeply located geological formations e.g. saline aquifers. During geological storage, **chemical dissolution** induces important and irreversible changes of the rock properties.

Objective is to propose a **methodology** which allows us to predict the evolution of effective mechanical behaviour of saline aquifers caused by microstructural changes due to **CCS**.

Advanced Morphological Analysis of Sandstone

The **starting point** is **CT scan** of microstructure of **Fontainebleau sandstone** of size 256x256x256 px, where 1 px = 5.01 microns.

Numerous types of morphological descriptors: porosity, sizing (granulometry), covariance function, connectivity (tortuosity).



[Tomography - pores]

Granulometry Function

$$G_r(X) = 1 - \frac{|X \circ B_r|}{|X|}$$

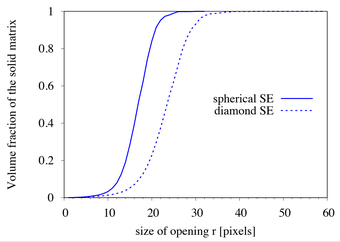
X – solid phase

B_r – structuring element of size r

$X \circ B_r = (X \ominus B_r) \oplus B_r$

$\ominus / \oplus$ –erosion / dilation

$|\cdot|$ – measure



Covariance Function

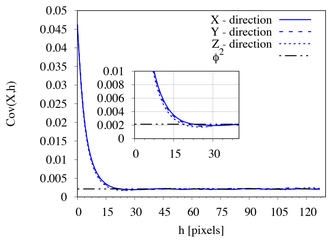
$$C(X, \vec{h}) = P\left\{x \in X, x + \vec{h} \in X\right\}$$

$P\{\cdot\}$ – probability

X – porous phase

x – arbitrary point

$\vec{h}$ – translation vector



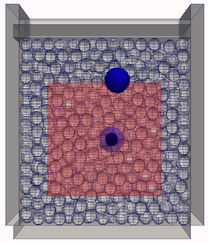
Summary:

$\varphi = 0.046$ $\quad \varphi_{eff} = 0.029$ $\quad$ percolated in all directions $\quad r_{mean} \in (17, 23)$ $\quad$ isotropy

Numerical Samples - Generation

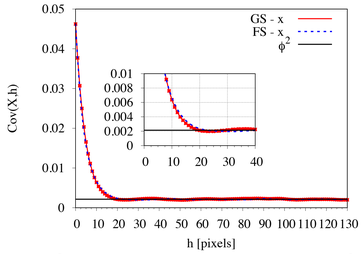
The method is inspired by natural formation process of sandstones [Bakke and Øren, 1997] and adjusted in order to respect aforementioned morphological properties:

1. grain deposit - monodisperse grains assembly of initial radius 14 px, deposed into 3D box,
2. triaxial compaction - bulk volume reduction,
3. diagenesis - mixed uniform and random radii increment to obtain desired value of porosity.

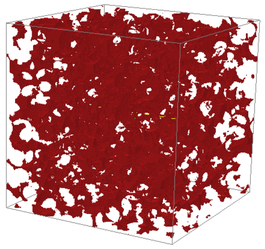


[Reconstruction method]

Generated samples (red box) are validated **a posteriori**.



[Comparison of covariance functions]



[Generated microstructure]

Numerical Dissolution by Morphological Dilation

Chemical dissolution of porous matrix is homogeneous at sample scale [Egermann et al, 2006]. We investigate two different scenarii of dissolution:

Isotropic

$$X_i = X_{i-1} \oplus B$$

Percolated Network

$$X_i = [\Xi(X_{i-1}) \oplus B] + X_0$$

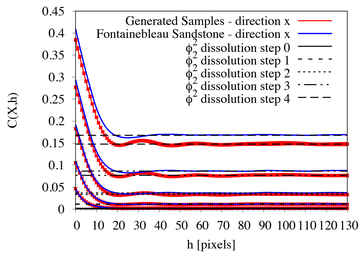
X_0 – binary image representing initial porous phase

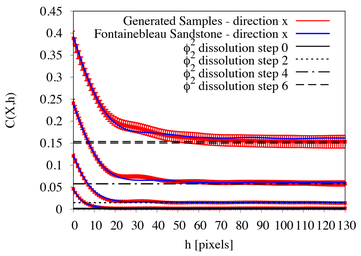
X_i – binary image of i-th dissolution step

$\oplus$ – morphological dilation

B – cubic SE (3x3)

$\Xi(\cdot)$ – operator extracting percolated network



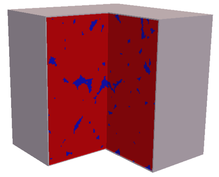


[Evolution of covariance functions of generated samples (red) and real microstructure (blue)]

Constant characteristic size $\qquad$ Increasing characteristic size

Elasticity - Periodic Homogenization

Method of numerical, periodic homogenisation:
problem: non-periodic geometry.
solution: additional layer of homogeneous material associated with



[External layer]

fixed point method: $c^{layer}_{klmn}[i] = c^{hom}_{klmn}[i-1]$

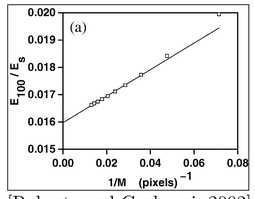
CT scan is naturally discretised (regular cubic mesh).
The influence of such discretization on the estimation of elastic moduli is given by [Garboczi and Day, 1995]:

$$P(M) = P_0 + \frac{a}{M}$$

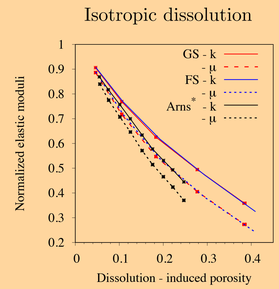
$P(\cdot)$ – computed elastic moduli

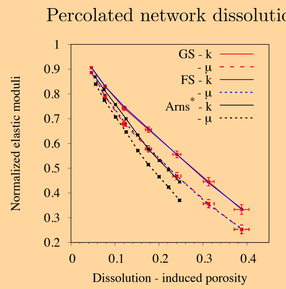
M – resolution

P_0 – searched value



[Roberts and Garboczi, 2002]





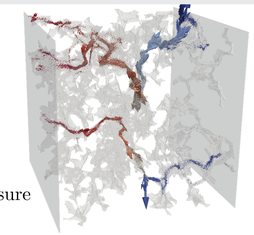
* Arns et al. 2002

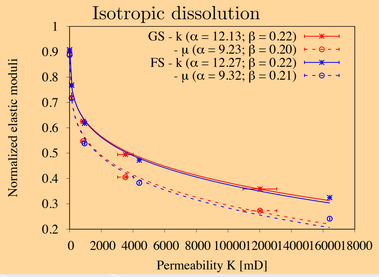
Permeability - Elasticity Coupling

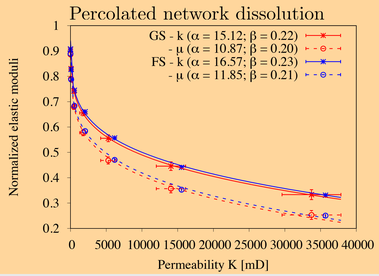
Darcy's law: $K = \frac{\mu Q L}{\Delta p A}$

Coupling: $P(K) = 1 - \frac{K^{\beta}}{\alpha}$

K – permeability
μ – dyn. viscosity
Q – flux
A – surface area
L – sample length
Δp – grad. of pressure







* kajetan.wojtacki@umontpellier.fr