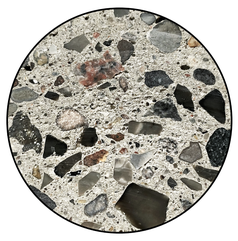
Porosity characterization of intact concrete specimens

Q. I. Roode-Gutzmer, J. Kulenkampff, A. Barkleit, T. Stumpf

Institute of Resource Ecology

Background / Motivation

biological shielding concrete



n / ɣ → radiation

defects in crystal lattice

structural relaxation

H_2O → pH > 10

alkali-silica-reaction

ASR

concrete → degradation

radionuclide

sorption / mobility

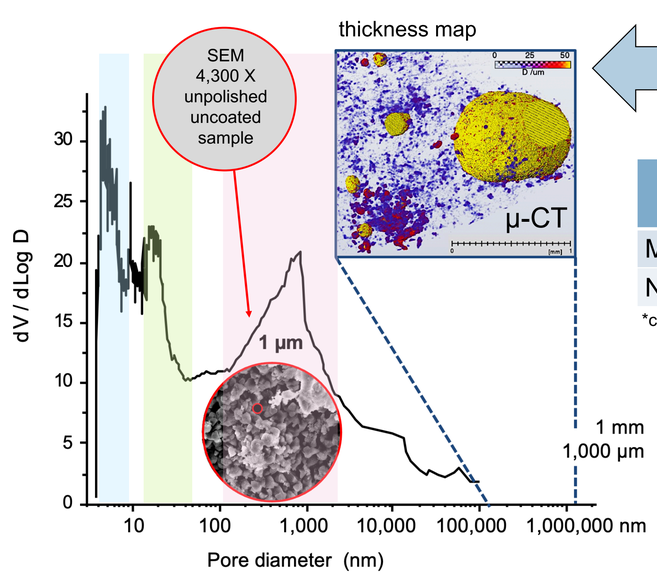
in situ via activation

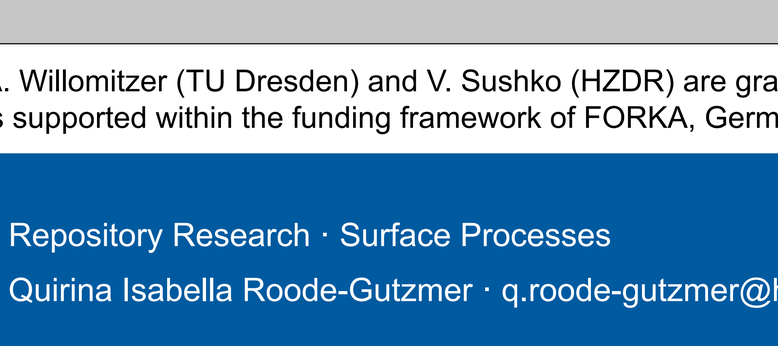
ex situ via leaking nuclear reactor cooling water

change in pore structure → we are here → shrinkage of hydration phases → expansion of aggregates → ingress of water → reactive transport → loss of mechanical properties → reactive transport

Experimental procedures / Evaluating initial pore structure

MIP measurement in accordance with ISO 15901-1





differential volume pore-size distribution curves determined by MIP of small intact cores of concrete illustrating pore features on the logarithmic scale

MIP ← µ-CT ← 0.14 g ← **2**

MIP ← µ-CT ← 0.99 g ← **F**

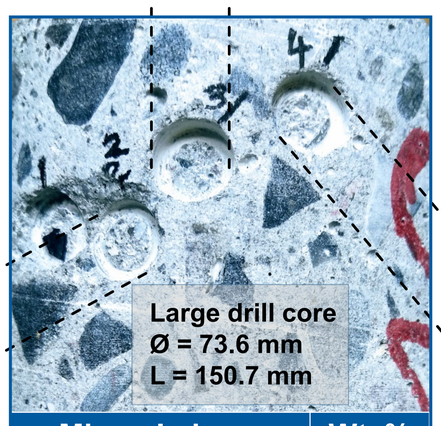
Ø ~ 5 mm

MIP ← N_2 / BET ← SEM ← µ-CT ← 0.17 g → collating MIP and µ-CT

3

Specific surface area, m^2/g	
MIP	9.94
N_2 / BET	6.07* (σ = 0.54)

*calculated using cylinder and plate model



Mineral phase	Wt. %
α-Quartz (SiO_2)	51.0
Potassium feldspar microcline ($KAlSi_3O_8$)	17.8
Amorphous: C-S-H	25.6
Portlandite: $Ca(OH)_2$	2.8
Calcite: $CaCO_3$	2.8

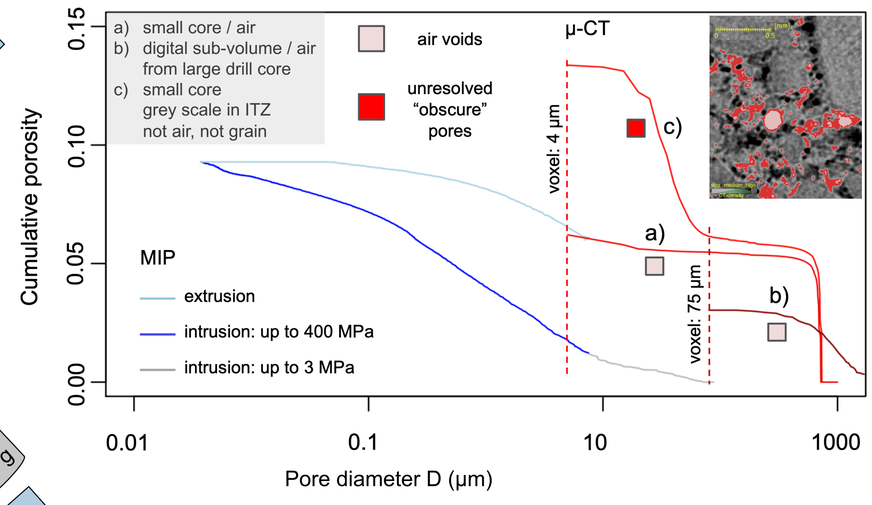
µ-CT	– Micro-Computed Tomography
MIP	– Mercury Intrusion Porosimetry
SEM	– Scanning Electron Microscopy
OM	– Optical Microscopy
BET	– Brunauer Emmett Teller
ITZ	– Interfacial Transition Zone
σ	– Standard Deviation
n	– Neutron
ɣ	– Gamma

	Porosity, %	
drill core position	µ-CT*	MIP
2	14.0	13.8
3	13.4	11.2
4	-	-
F	-	7.32

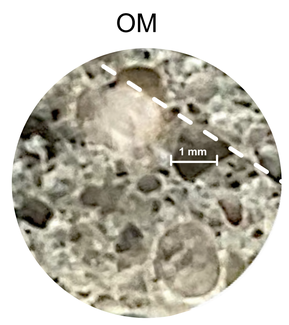
*calculated from thickness map (spheres are mathematically fitted into spaces possessing grey-scale density corresponding to air)

4

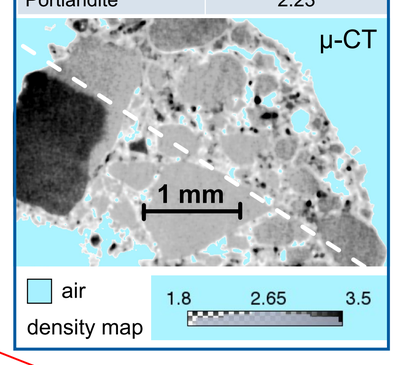
0.16 g → µ-CT → SEM



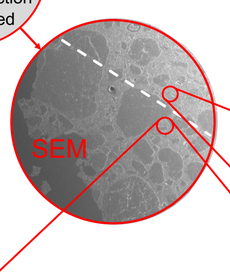
OM

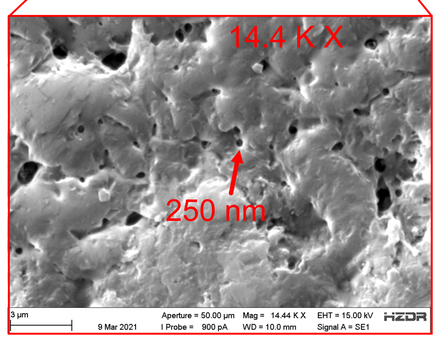


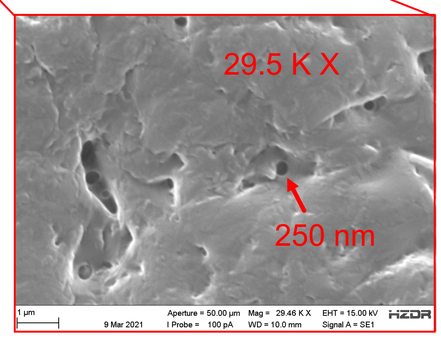
Mineral phase	Density, g/cm³
Calcite	2.71
Quartz	2.65
C-S-H	2.60
Microcline	2.56
Portlandite	2.23



SEM
43 X
vacuum impregnated polished section gold coated







Experimental outcomes / Future objectives

Porosity of small intact specimens (0.15 ± 0.01 g) were characterized.

MIP: connected pores in 1D on nanoscale (quantitative / destructive)
SEM: porosity in 2D on nano- to micro-scale (qualitative / semi-destructive)
µ-CT: total porosity in 3D on microscale (quantitative / non-destructive)

MIP: ● hysteresis due to deviation from capillary bundle model ● ink-bottle effect (large pores with narrow throats) ● smaller pores over-estimated at expense of larger pores ● specific surface area MIP > N_2/BET due to fracking and non-equilibrated capillary pressure

Examining radiation-induced changes in 3D:
- shrinkage of hydration phases
- expansion of aggregates
- tracking ASR-formation

Acknowledgements

A. Willomitzer (TU Dresden) and V. Sushko (HZDR) are gratefully appreciated for respectively carrying out the MIP measurements and for assisting with SEM imaging. This work is supported within the funding framework of FORKA, German Federal Ministry of Research and Education (WERREBA project: Grant Number 15S9412).

Repository Research · Surface Processes

Quirina Isabella Roode-Gutzmer · q.roode-gutzmer@hzdr.de · www.hzdr.de

Partner von DRESDEN concept exzellenz-dresden.de

Bundesministerium für Bildung und Forschung

FORKA – Forschung für den Rückbau kerntechnischer Anlagen

Förderkonzept: Rückbau und Entsorgung