Analytical methods: computed microtomography (μCT)

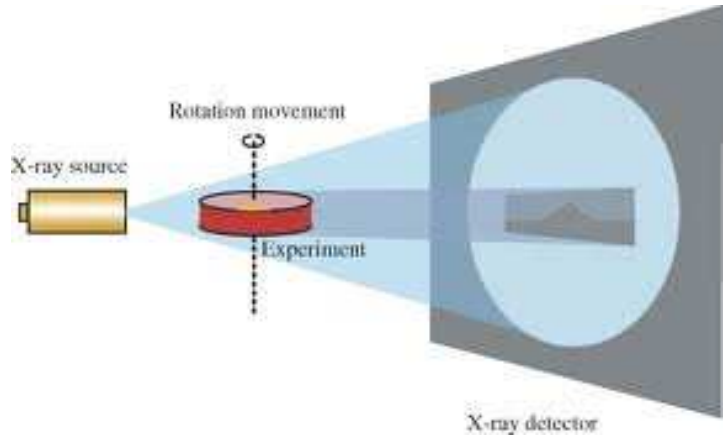
Workshop “Review of Geopolymers”,
IRSM, 17.10-21.10.2011,
Prague

Overview of presentation

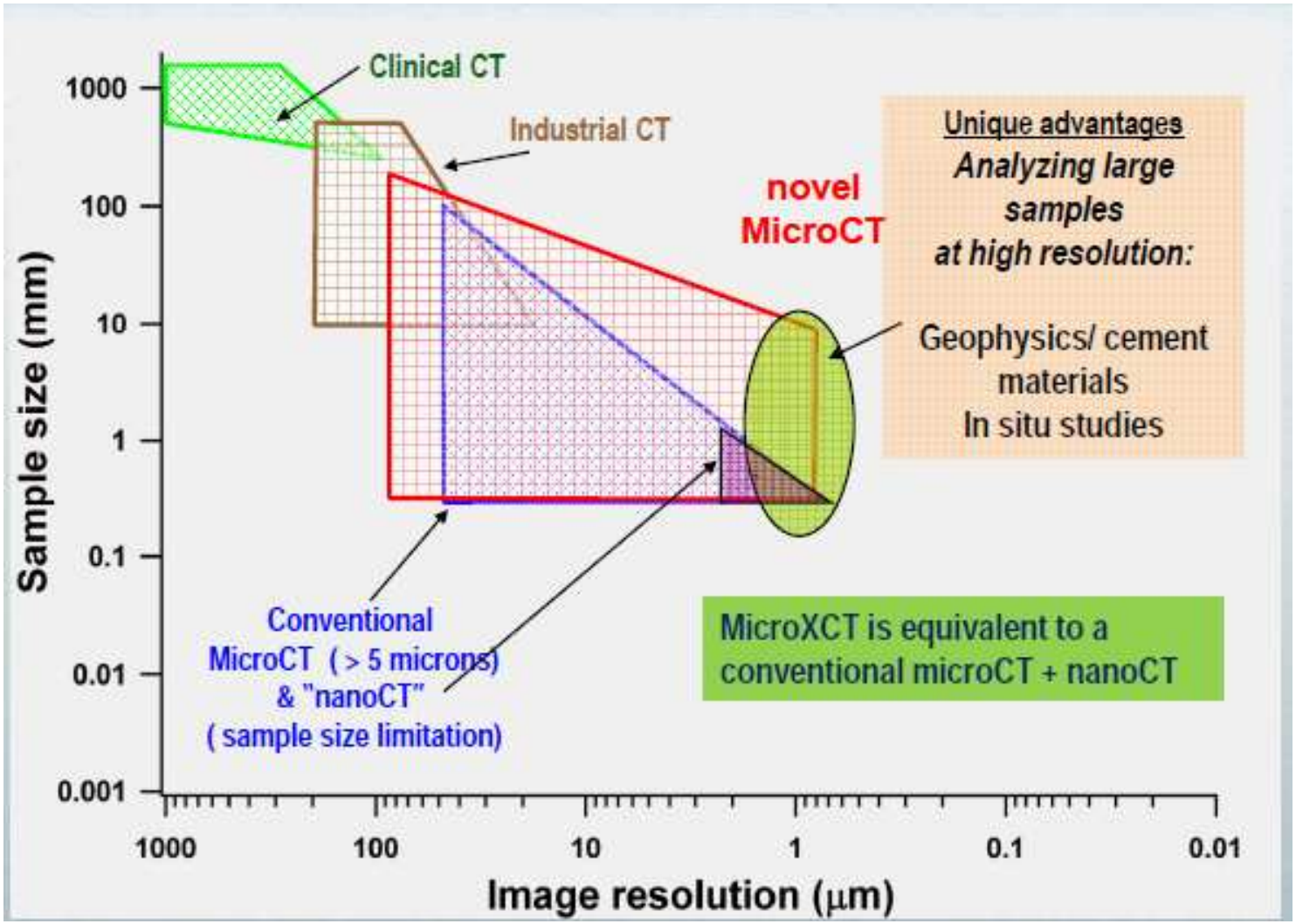
- History of μCT
- Applications of μCT
- Research possibilities of μCT in geopolymers research
  - Examples from literature
  - Future is now (nanotomography)
- μCT400 @ ZAG (μCT of geopolymer from EMABM2011 workshop)
- Conclusions

What is x-ray microtomogaphy

- X-ray microtomography (also frequently referred to as micro CT) is a radiographic imaging technique that can produce 3D images of a material's internal structure at a spatial resolution < 1 um.



- Minimal preparation of material - NDM


Clinical CT
Industrial CT
novel
MicroCT
Unique advantages
Analyzing large
samples
at high resolution:
Geophysics/ cement
materials
In situ studies
Conventional
MicroCT (> 5 microns)
& "nanoCT"
(sample size limitation)
MicroXCT is equivalent to a
conventional microCT + nanoCT
Sample size (mm)
1000
100
10
1
0.1
0.01
0.001
1000
100
10
1
0.1
0.01
Image resolution (μm)

History

- R… …al
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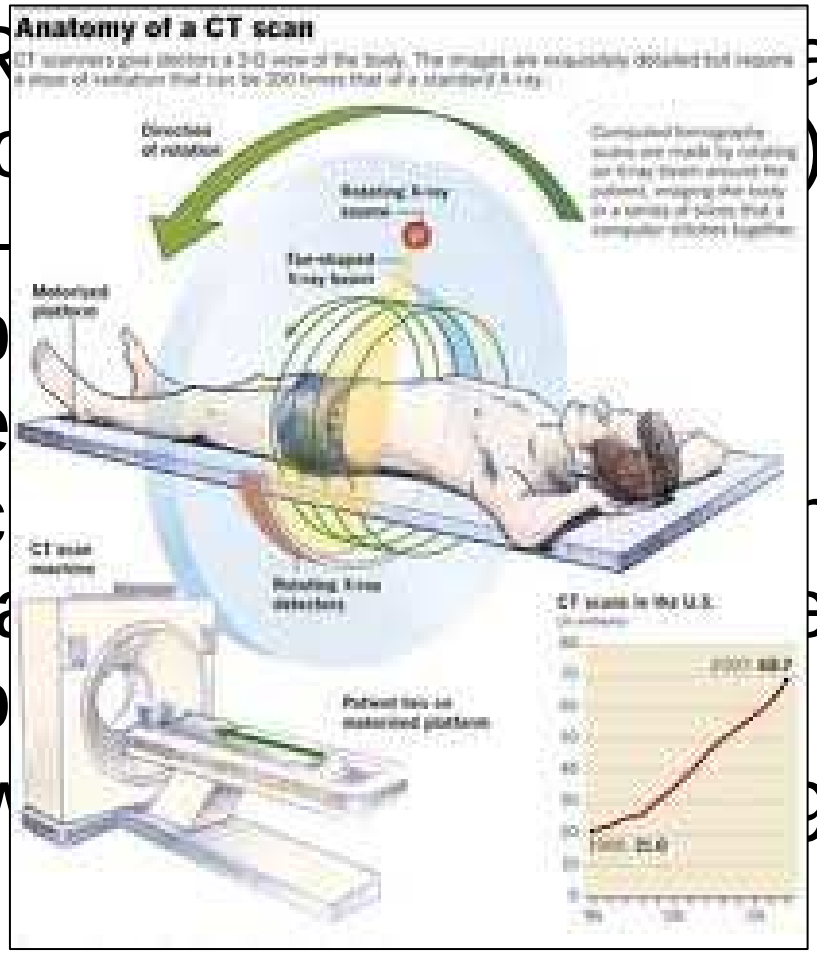
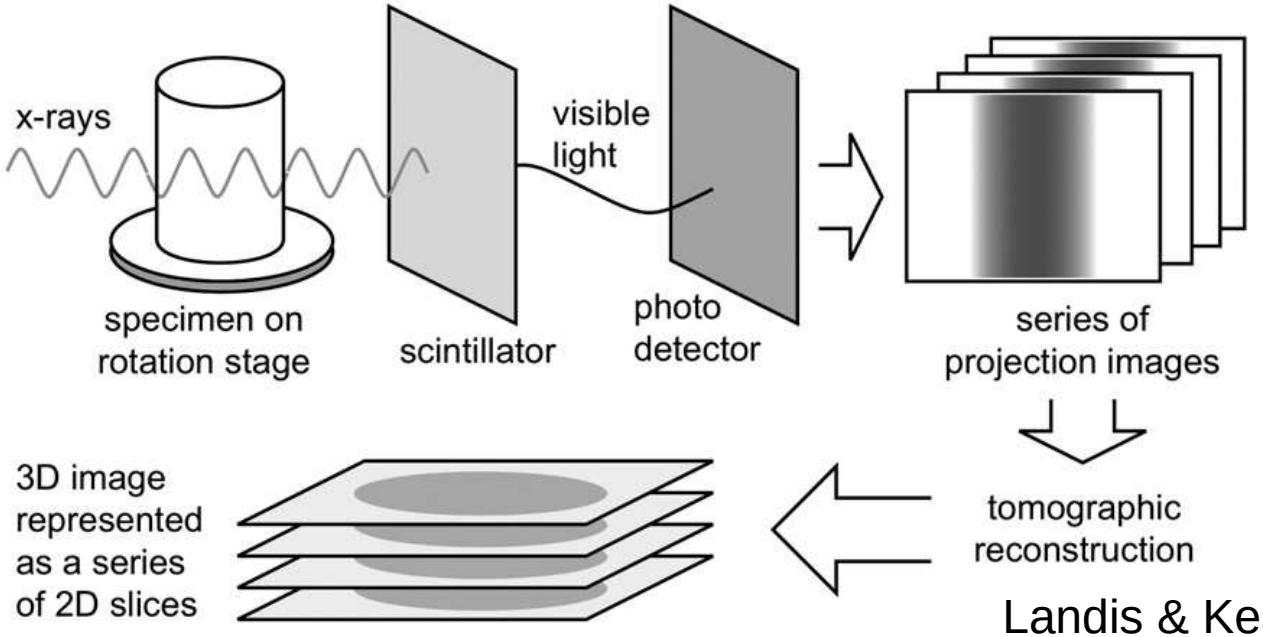
- W… …95



- Schematic illustration of X-ray CT acquisition and reconstruction processes.

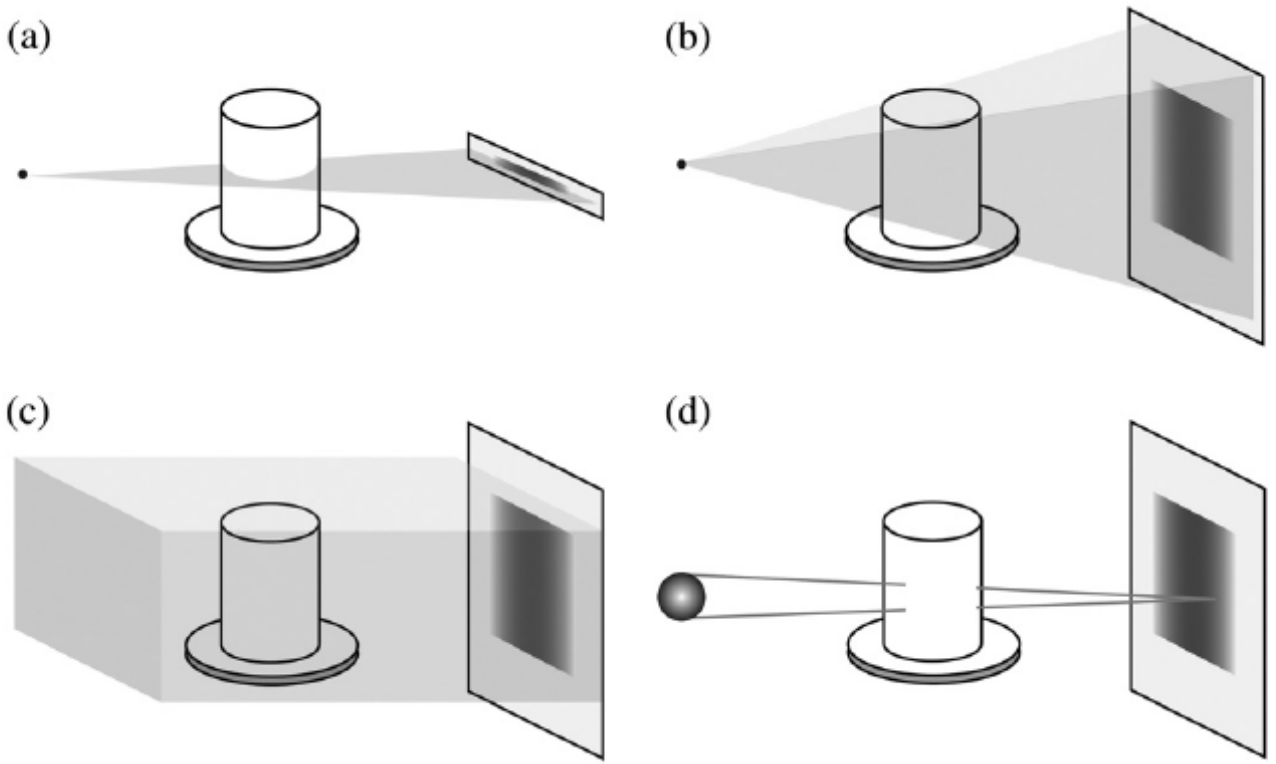


Landis & Keane, 2010

A series of X-ray projection images is acquired and mathematically reconstructed to produce a 3D map of X-ray absorption in the volume. The 3D map is typically presented as a series of 2D slice images.

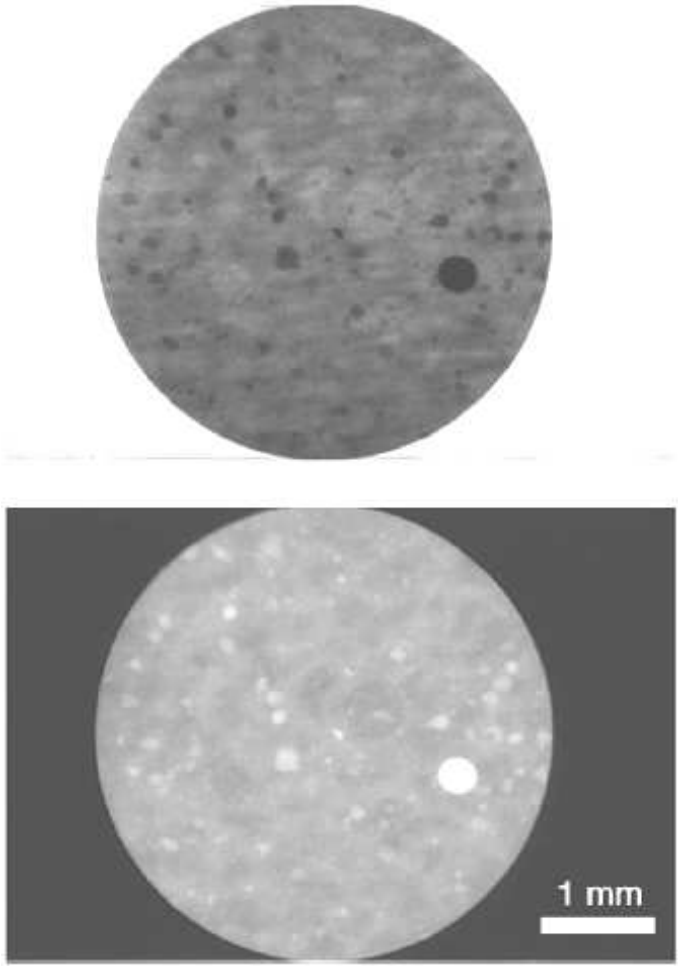
E.N. Landis & D.T.Keane, 2010: X-ray microtomography. Materials characterization 61,1305-1316.

- SPOT SIZE of x-ray source

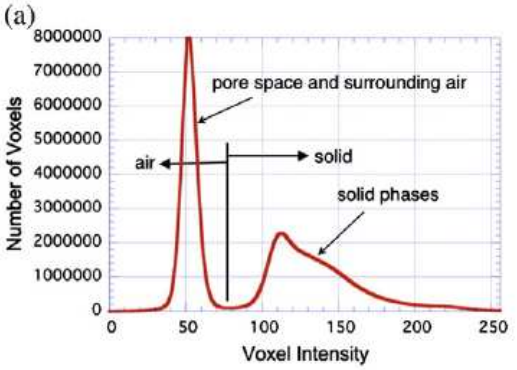


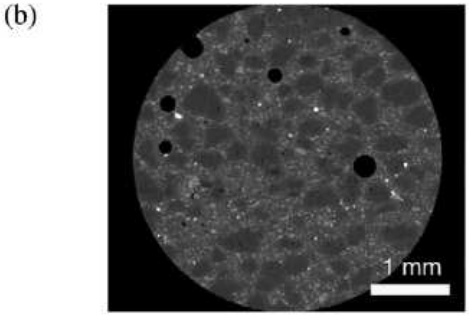
Applications of microtomography

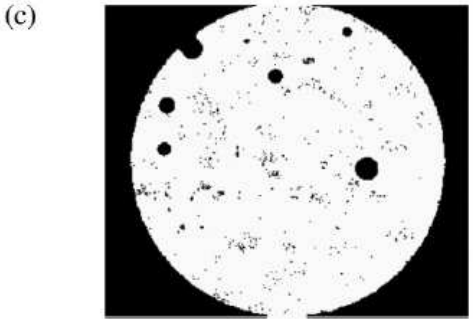
- X-ray absorption in material depends on:
  - Number of atoms (density, thickness)
  - Type of atoms (z-number)
- Where the sample absorbs more X-rays, the image is darker; where it transmits more, the image is brighter
- Absorption increases with density and thickness, and it is also generally higher for elements with a higher atomic number in the periodic table



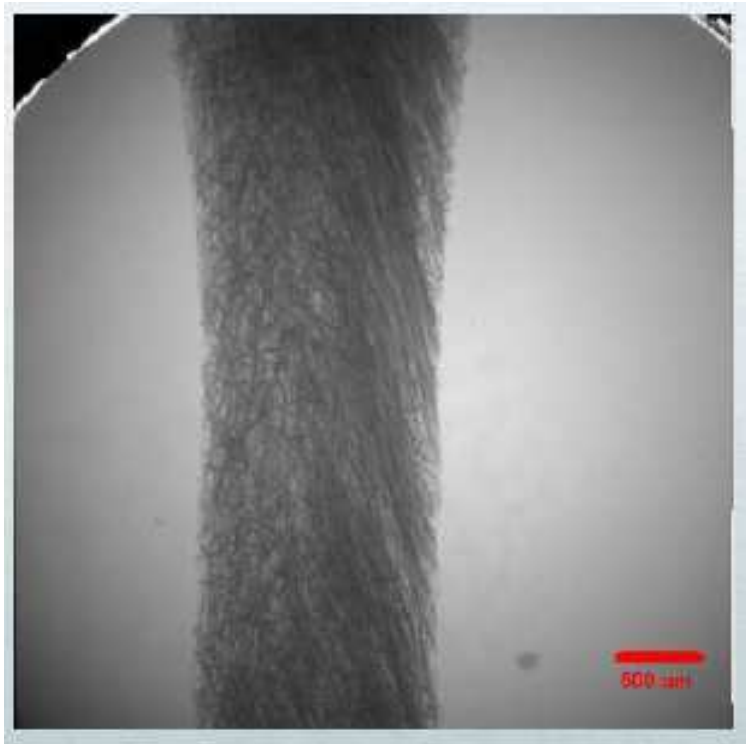
- 3D map of x-ray absorption → IDENTIFYING DIFFERENT PHASES
- Wide array of quantitative measurements on internal structure:
  - pase volume fractions and phase connectivity,
  - spatial distributions,
  - orientations,
  - alignment,
  - and connectivity of microstructural features.
- Problems: overlapping intensity distribution – example concrete, similar absorption levels among phases

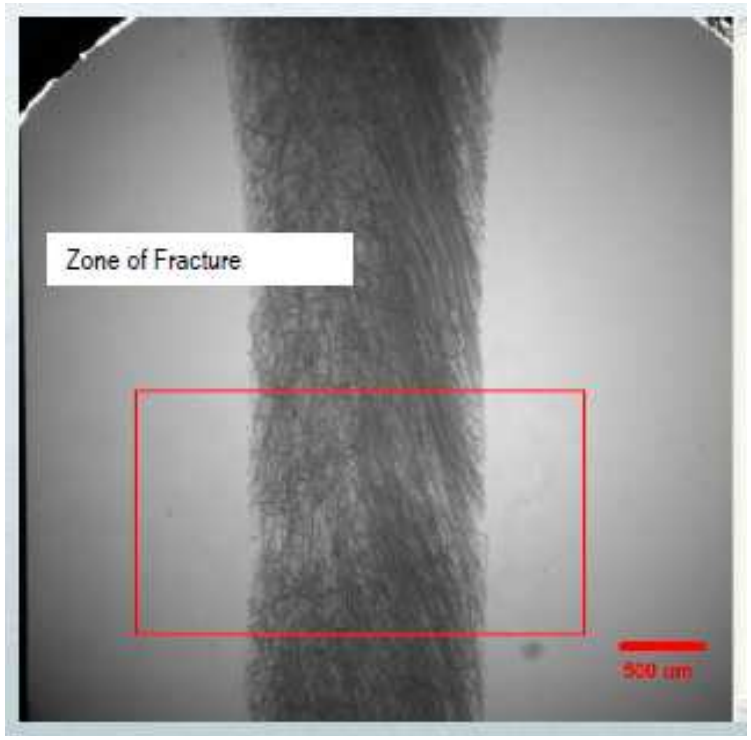






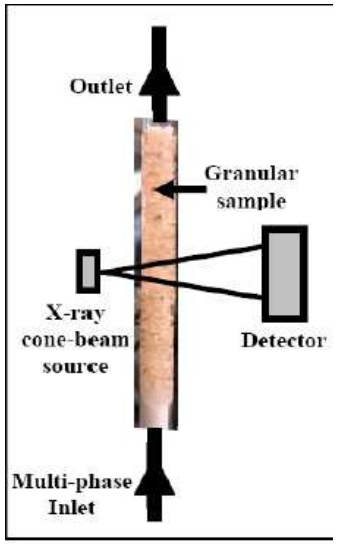
- Micromechanical mesurements

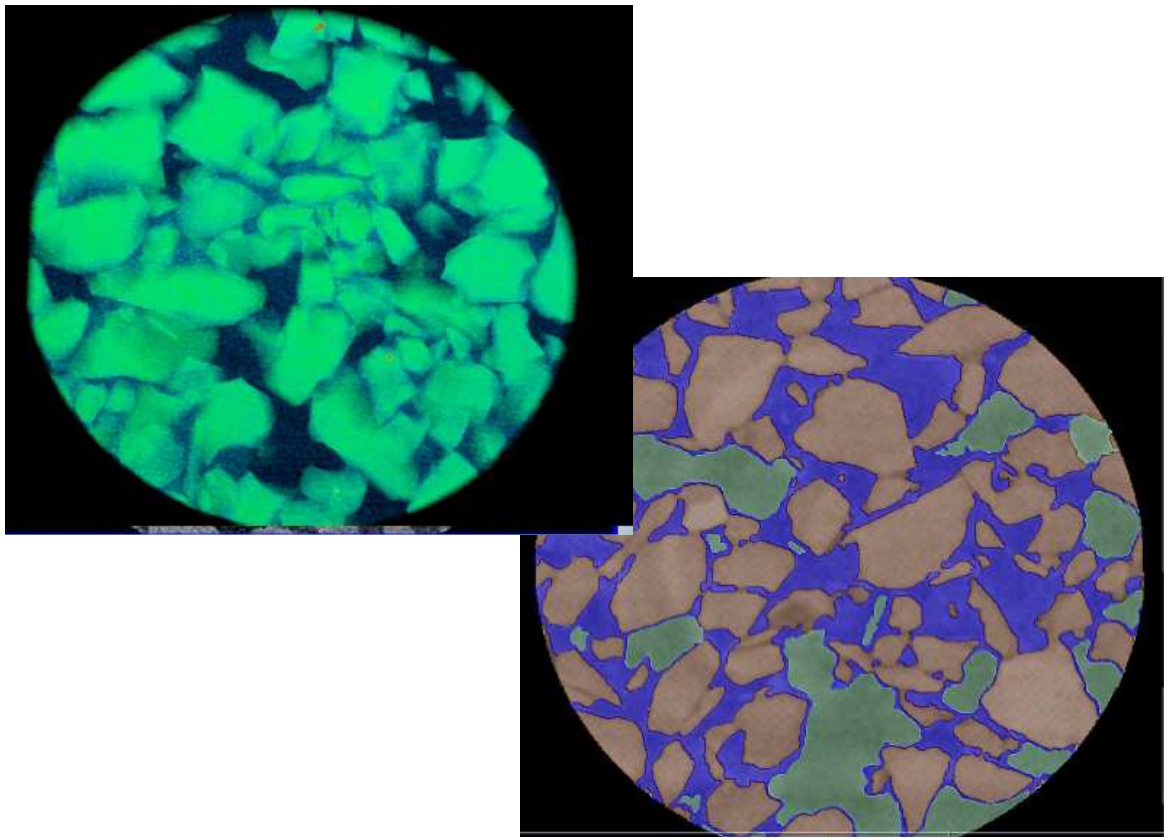




X-Radia

- Visualizing air-water-composite interface

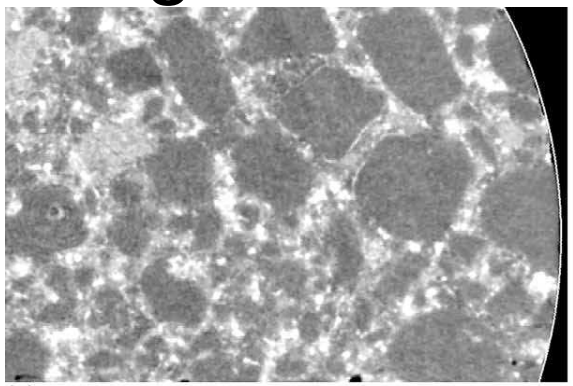




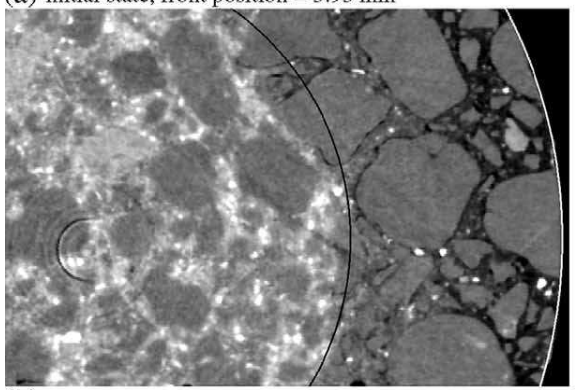
X-Radia

More examples from literature...

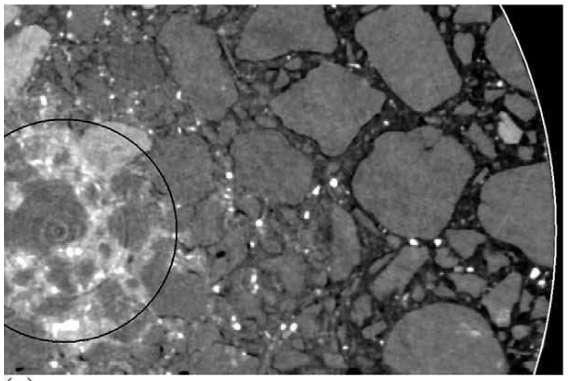
- Leaching of cementitious materials



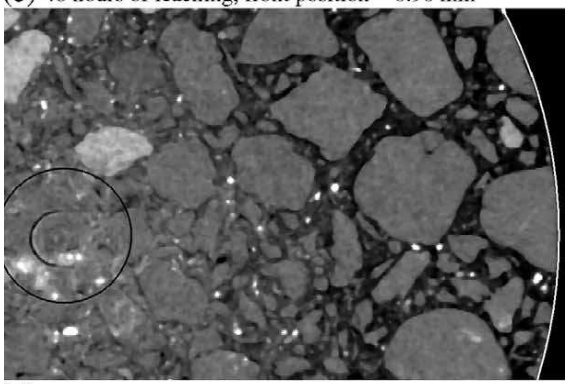
(a) initial state, front position = 3.93 mm



(b) 24 hours of leaching, front position = 2.25 mm



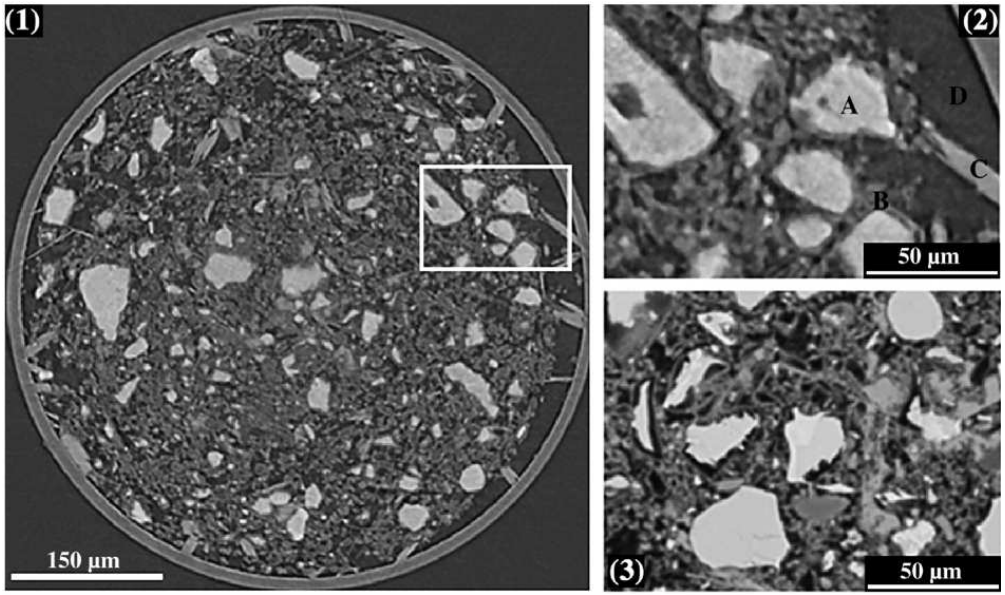
(c) 48 hours of leaching, front position = 0.90 mm

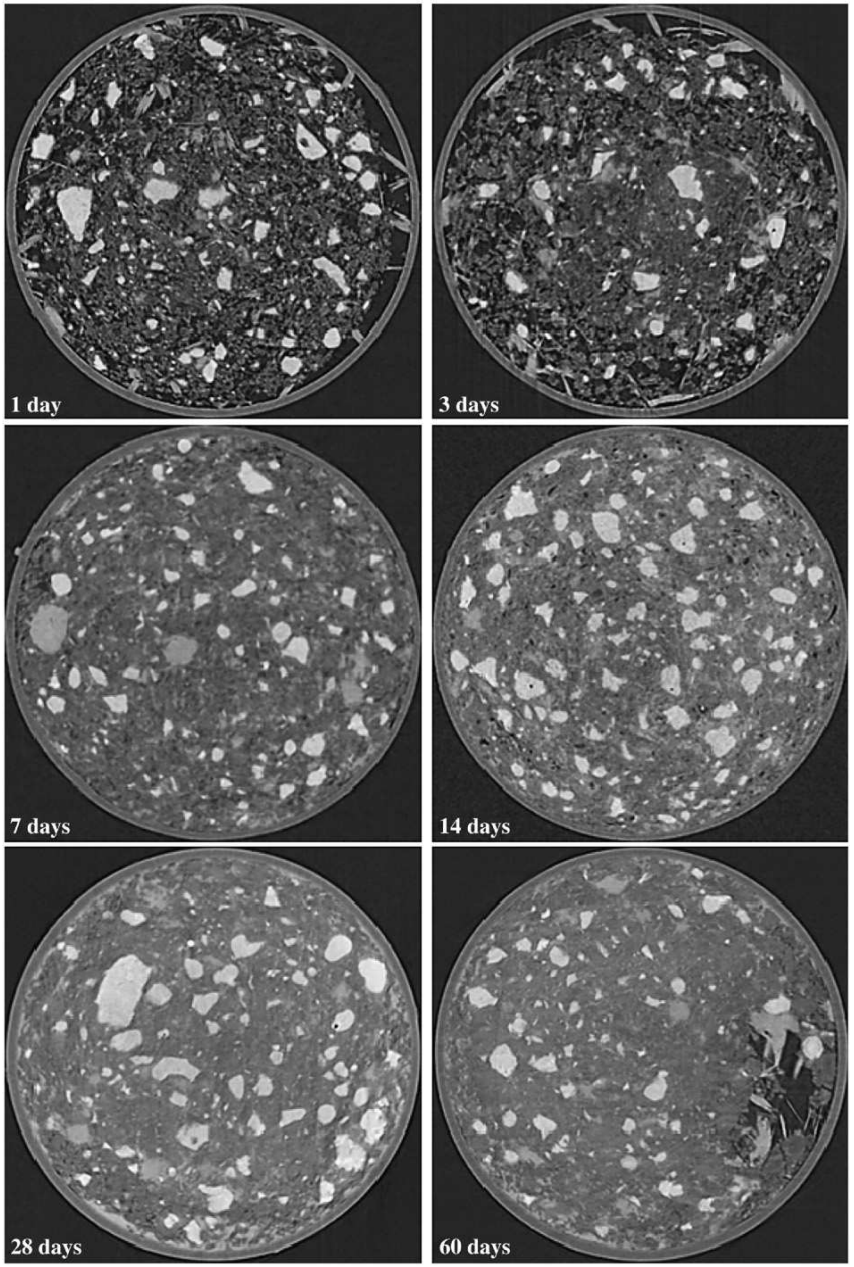


(d) 61 hours of leaching, front position = 0.58 mm

Burlion, Bernard & Da Chen, 2006: X-ray microtomography: Application to microstructure analysis of a cementitious material during leaching process. Cement and concrete Research 36, 346-357.

- Evolution of the microstructure of cement paste (Gallucci et al. 2007)

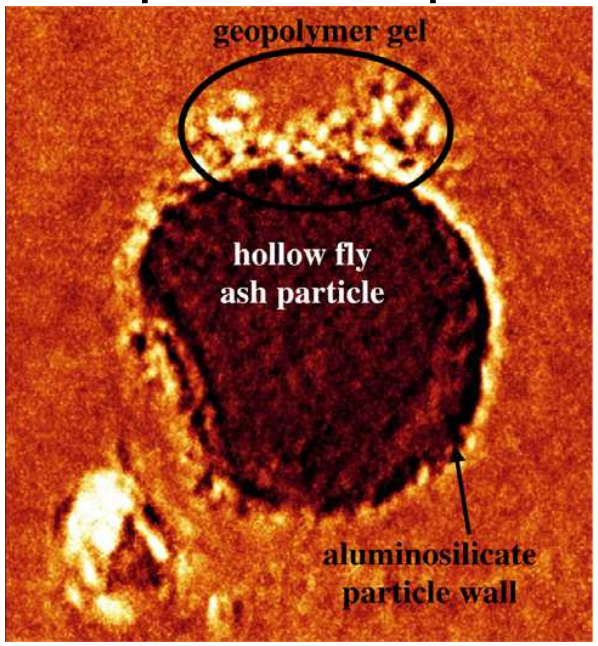




E. Gallucci, K. Scrivener, A. Groso, M. Stampanoni, G. Margaritondo, 2007: 3D experimental investigation of the microstructure of cement pastes using synchrotron X-ray microtomography (µCT). Cement and Concrete Research 37 (2007) 360–368.

Future is now: nanotomography

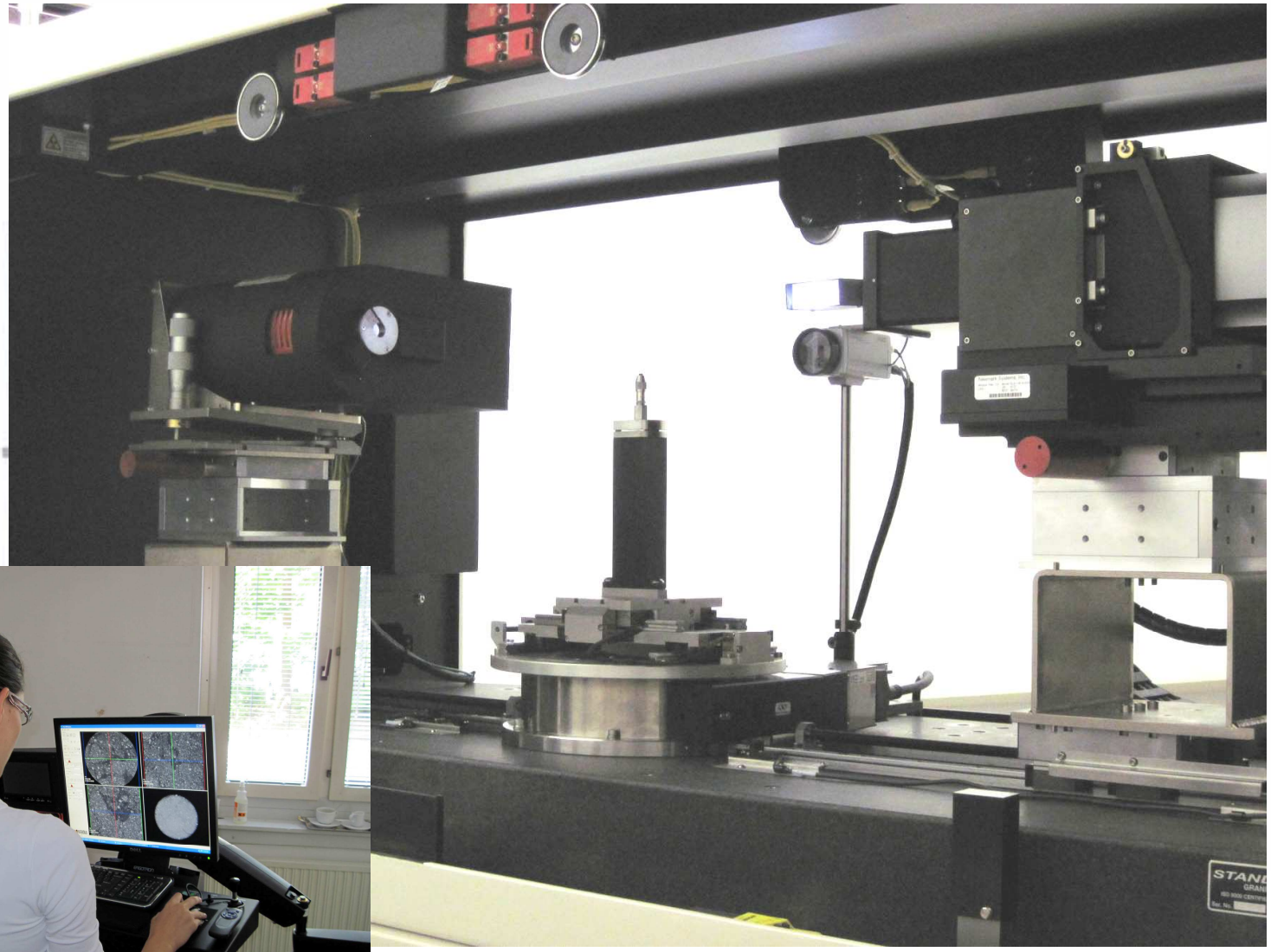
- Provis et al. 2011: the first 3D view of the pore structure of the aluminosilicate geopolymer gel (low CO2 GP*), as well as evidence for direct binding of geopolymer gel onto unreacted fly ash precursor particles.

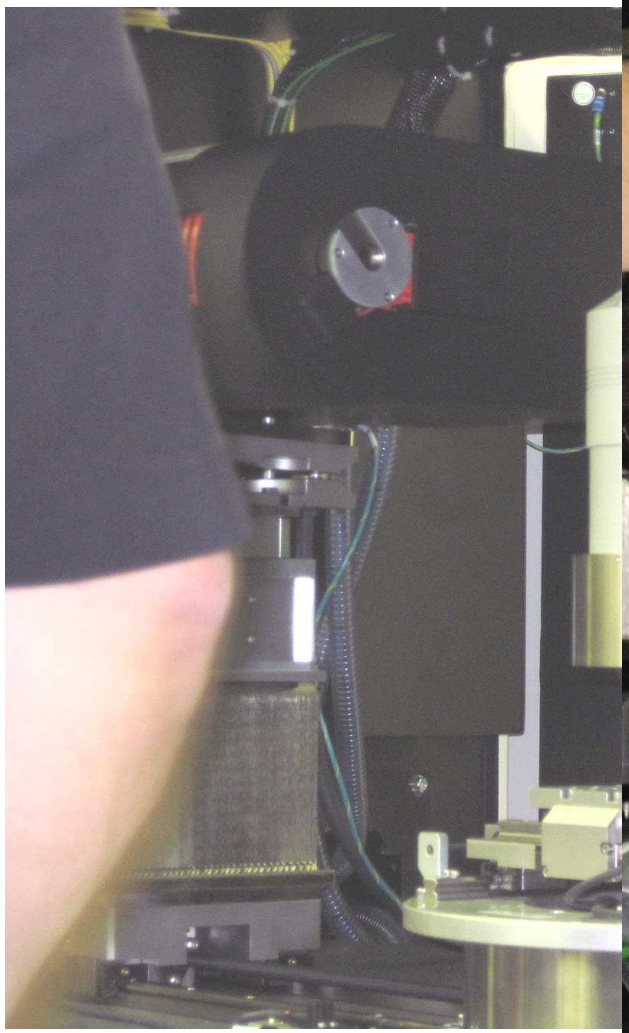


*80% CO2 savings against Portland cement

John L. Provis, Volker Rose, Robert P. Winarski, Jannie S.J. van Deventer, 2011: Hard X-ray nanotomography of amorphous aluminosilicate cements. Scripta Materialia 65,316-319.

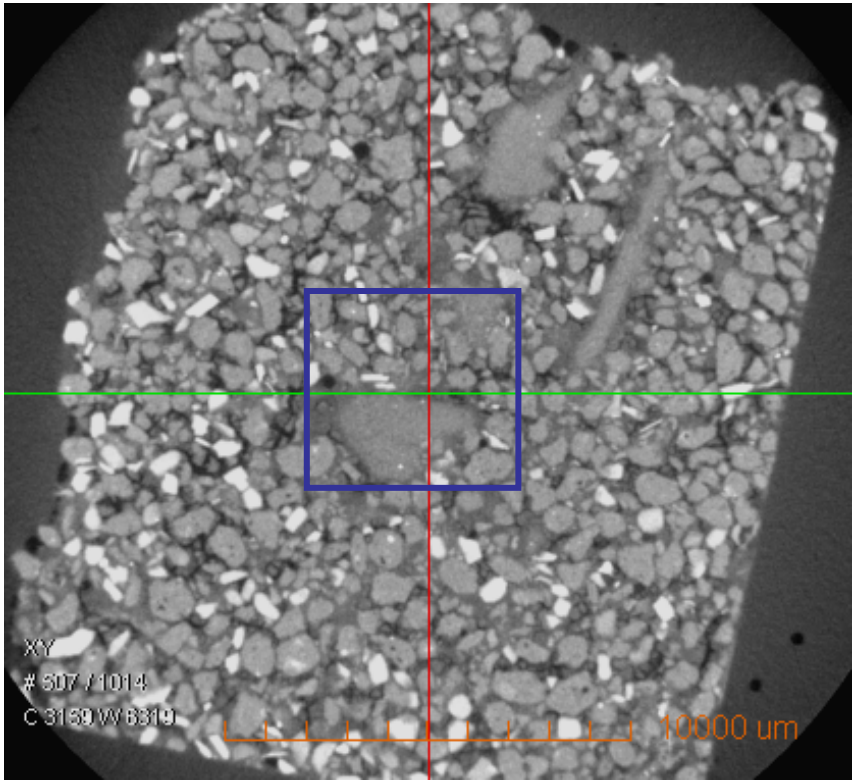
microXCT400 at ZAG

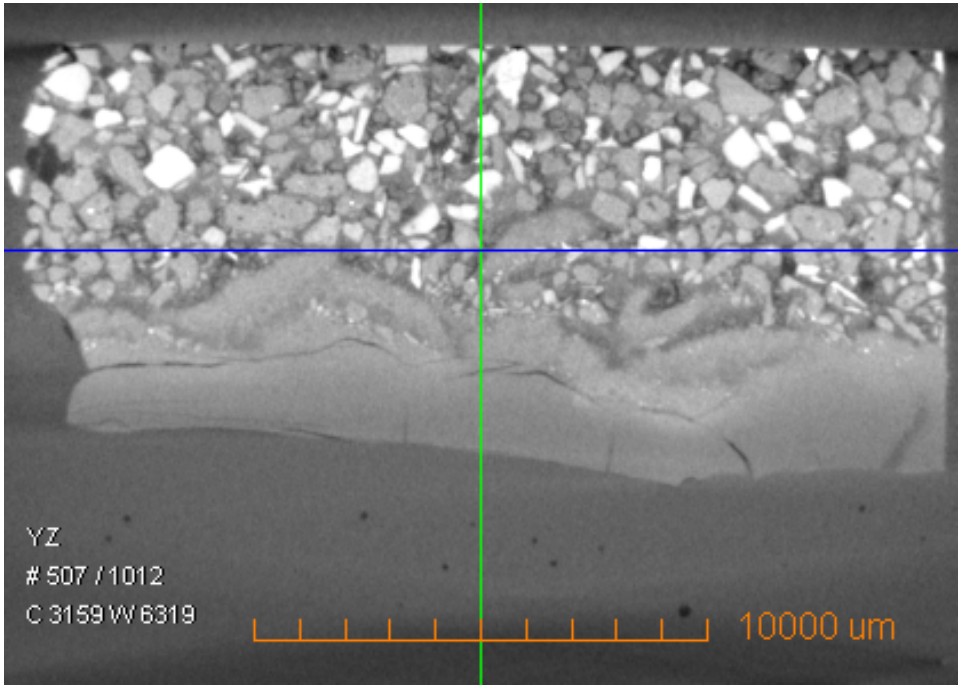


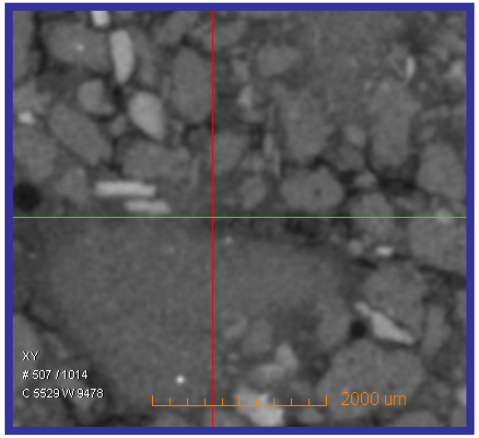


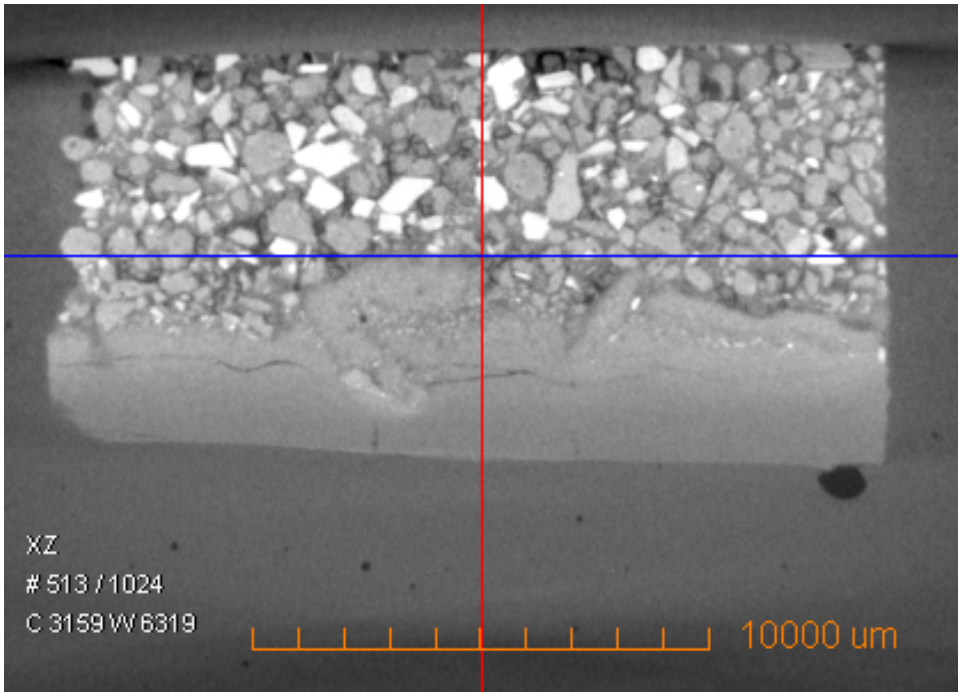
uCT of geopolymer on ZAG

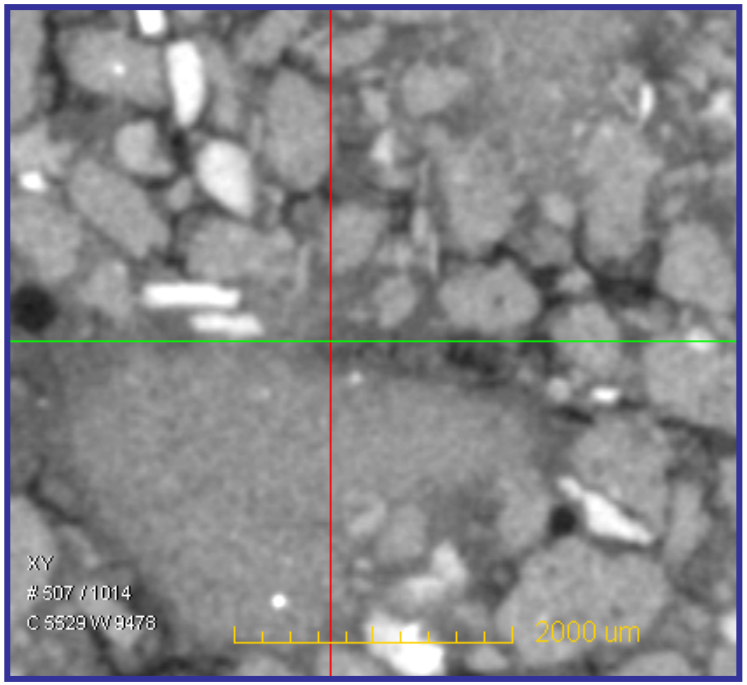
- Polished sections presented @EMABM2011 – Geopolymer workshop

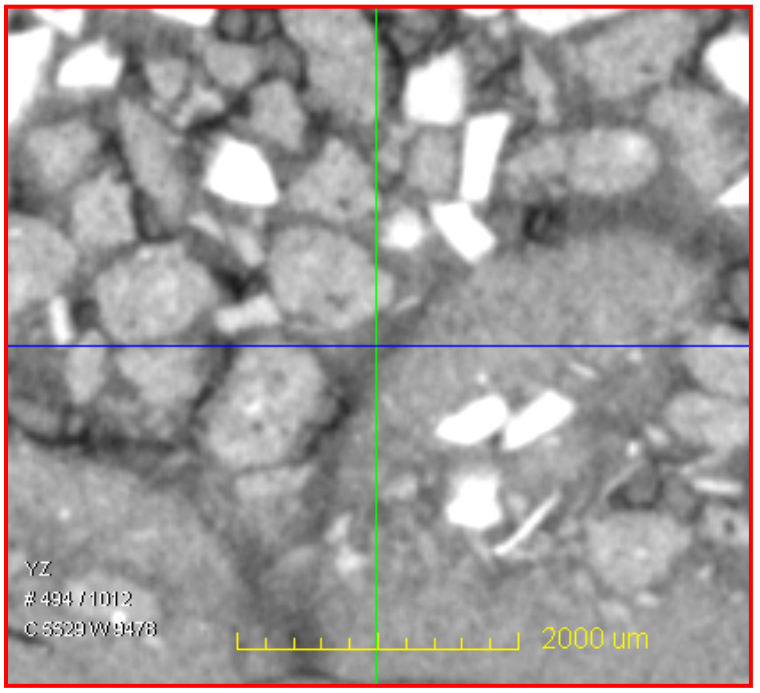

XY
507 / 1014
C 3159 W 6319
10000 um

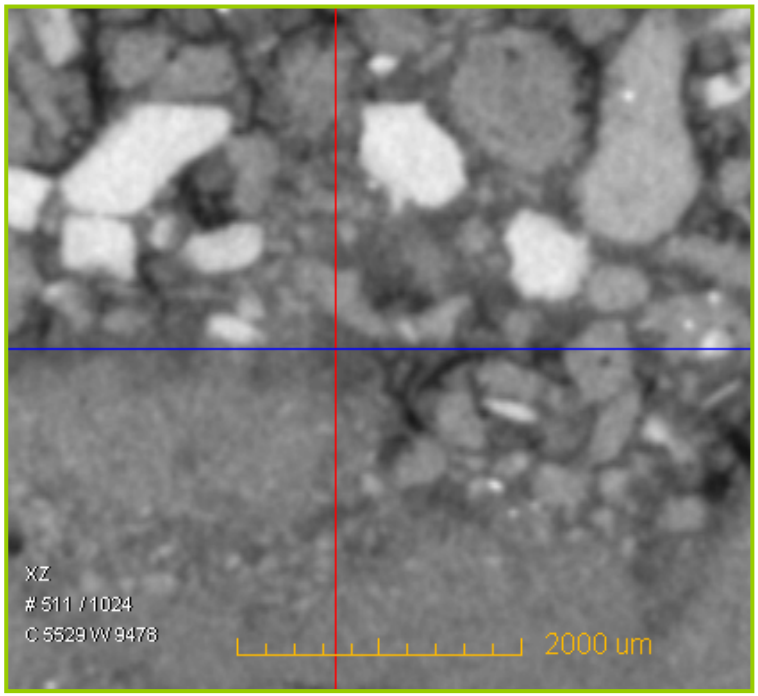

YZ
507 / 1012
C 3159 W 6319
10000 um

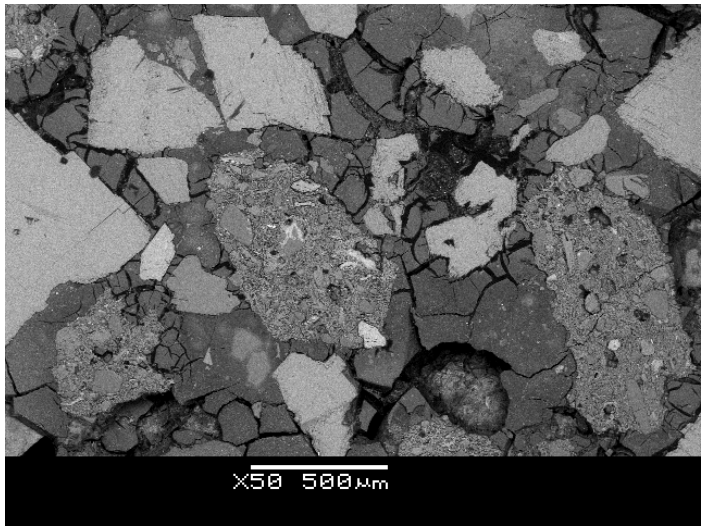

XY
507 / 1014
C 5529 W 9478
2000 um

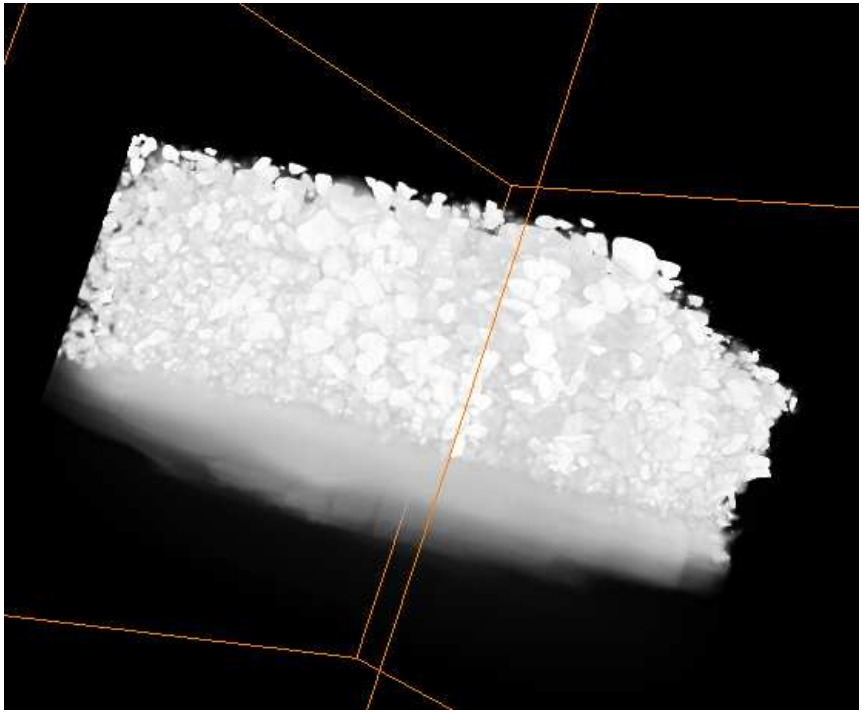

XZ
513 / 1024
C 3159 W 6319
10000 um

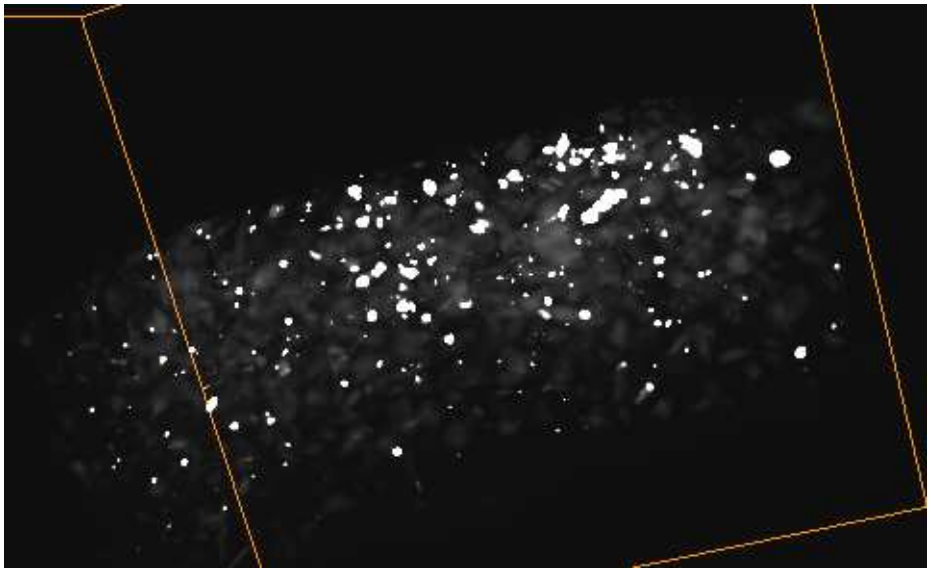

XY
507 / 1014
C 5529 W 9478
2000 um


YZ
494 / 1012
C 5529 W 9478
2000 um


XZ
511 / 1024
C 5529 W 9478
2000 um


X50 500µm





Conclusion

- 3D visualisation and identification of phases, simulation of water flow properties and in-situ testing
- Limitations:
  - penetrating ability of the X-rays relative to the density of the material sample. Dense metals, for example, require either very high-energy X-rays, or very small specimens.
  - Similarly, the method suffers when the material phases have large differences in X-ray absorption. In such a case, the resulting images will have very poor contrast within the less absorptive phases.
  - Relatively expansive method, limited availability.

Děkuji vám za Vaši pozornost!