

# Using a combined CT scan / Scanning Electron Microscope (SEM/EDX) protocol to appraise and better understand ASR-induced expansion and deterioration in concrete

**Leandro F. M. Sanchez, PhD, P.Eng**

Associate Professor – Department of Civil Engineering

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**Dr Andreas Leemann, Dr Michele Griffa**

Empa - Swiss Federal Laboratories for Materials Science and Technology



# Introduction

ASR → one of the most harmful deterioration mechanisms (critical infrastructure)

ASR → alkali hydroxides (pore solution) unstable mineral phases (aggregates)

Gel → water uptake from the surroundings (induced swelling and cracking)



Macroscale !



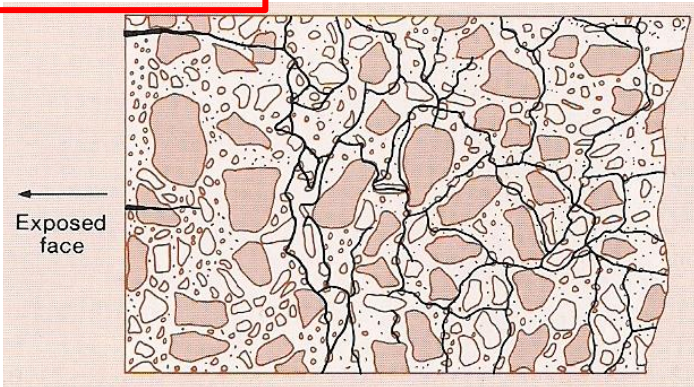
# Introduction

Mesoscale → understanding of induced deterioration mechanism (free expansion)

Cracks → aggregates (initial phases), and cement paste (advanced phases)

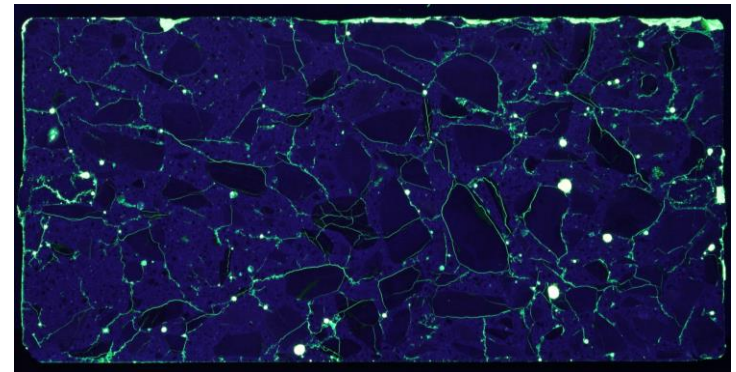
Mechanical properties losses → function of ASR-induced development

**AAR: sand**



**AAR: coarse aggregate**

**Mesoscale !**



Sanchez et al. 2015/2016

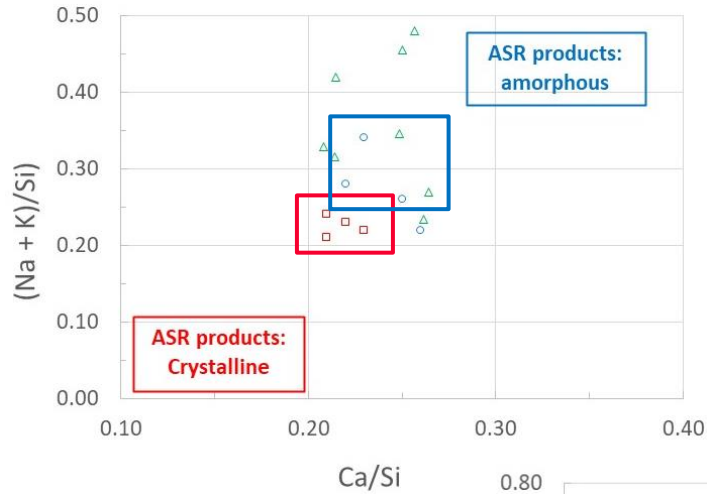
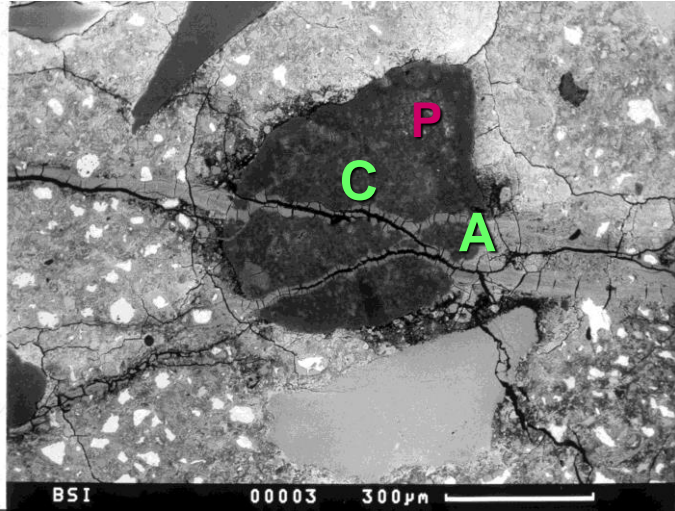
**Engineering perspective: better decision making!**

**Not enough to understand the induced process !**



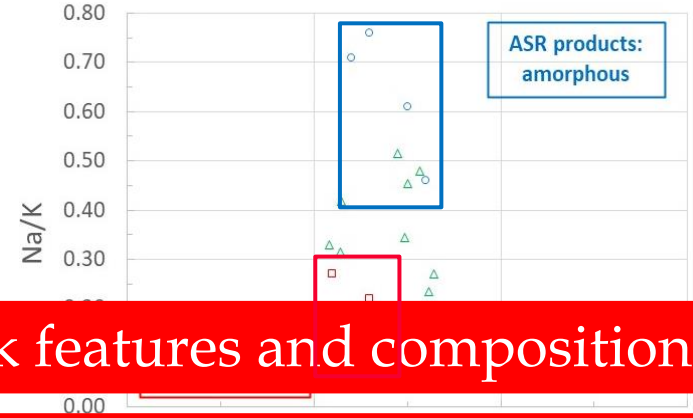
# Introduction

Microscale → mechanism governing ASR-induced development (SEM)



**Microscale !**

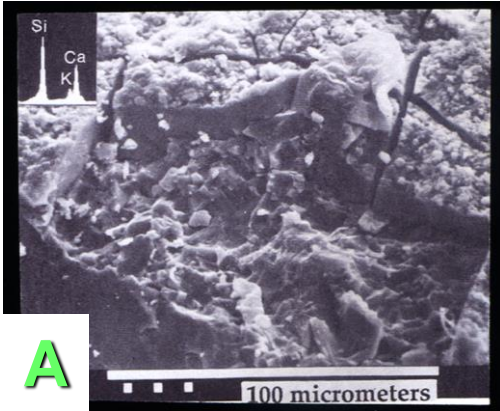
Fournier 2010



**SEM: microscopic crack features and composition**

**SEM: very difficult damage quantification**

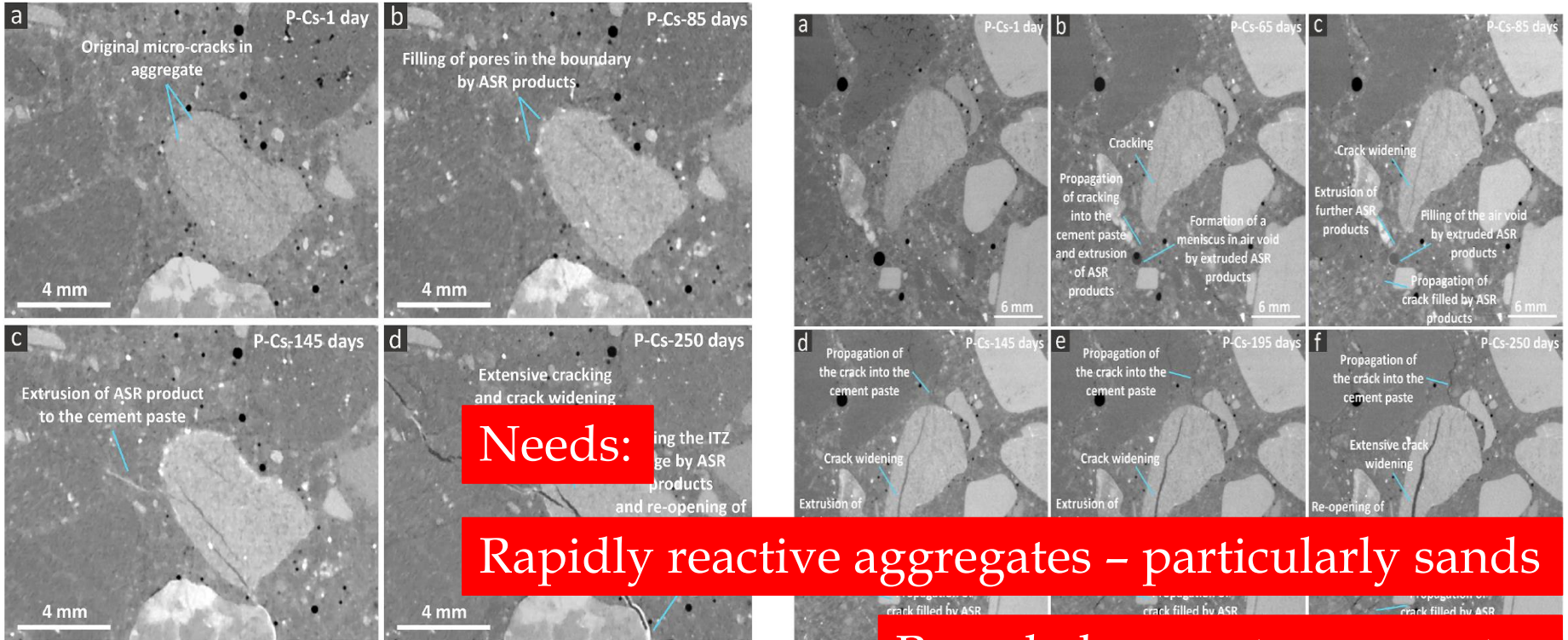
**Destructive procedure: do not allow time-lapse appraisal**



# Introduction

CT Scan → nondestructive procedure (reuse of specimens)

Cracks evolution as a function of time and induced expansion



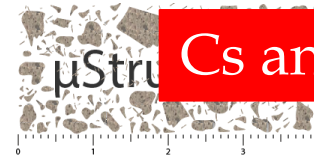
**Needs:**

**Rapidly reactive aggregates – particularly sands**

**Recycled concrete aggregates**

**Cs and barite as tracers !**

Shakoorioskooie et al.

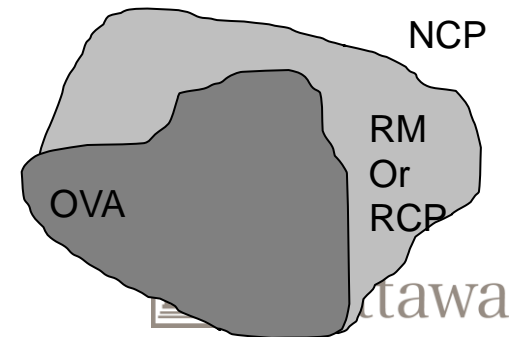
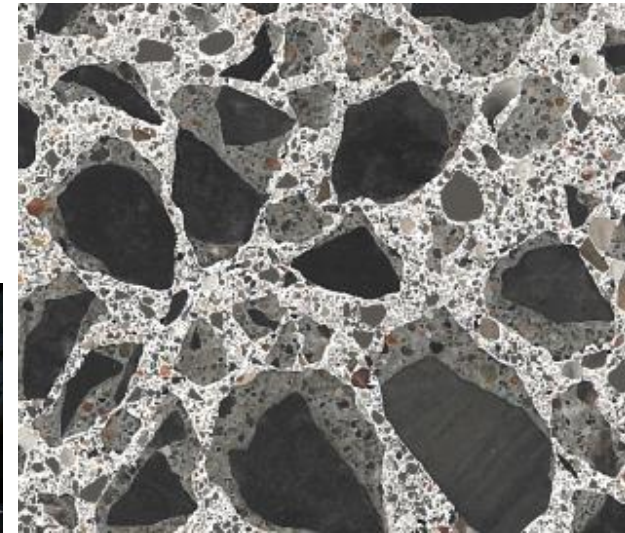


# Objectives

Coupled SEM and CT approach → ASR-induced development

Coarse and fine highly reactive natural aggregates

Recycled concrete aggregates made of highly reactive fine and coarse aggregates with 0.30% primary expansion in concrete



# Materials & Methods



35 MPa concrete specimens with  $\neq$  reactive aggregate types (i.e., fine vs coarse, conventional vs recycled)

Specimens stored in conditions enabling ASR development (0.4M & 38°C)

Evaluation over time (3-4w; 11-12w; 16w; and 24w)



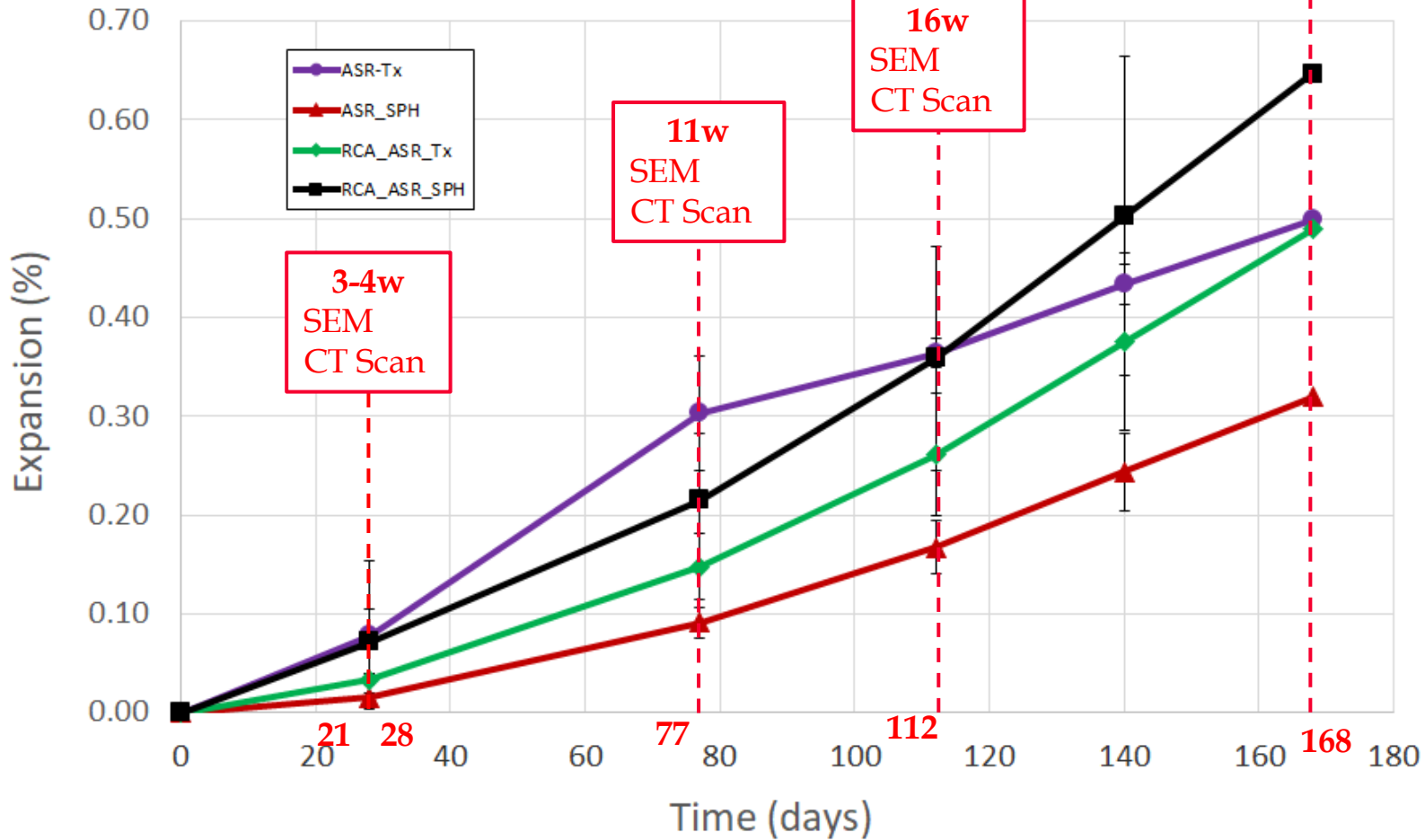
CT Scan

SEM analysis

Evaluation and interpretation of results

# Preliminary results

## Induced expansion over time



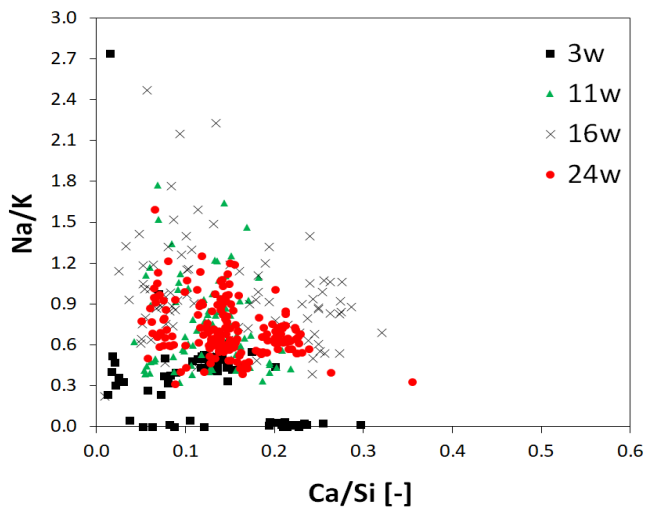
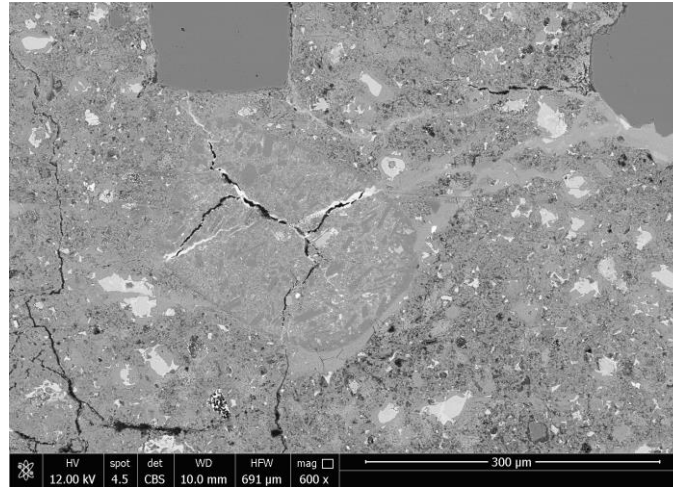
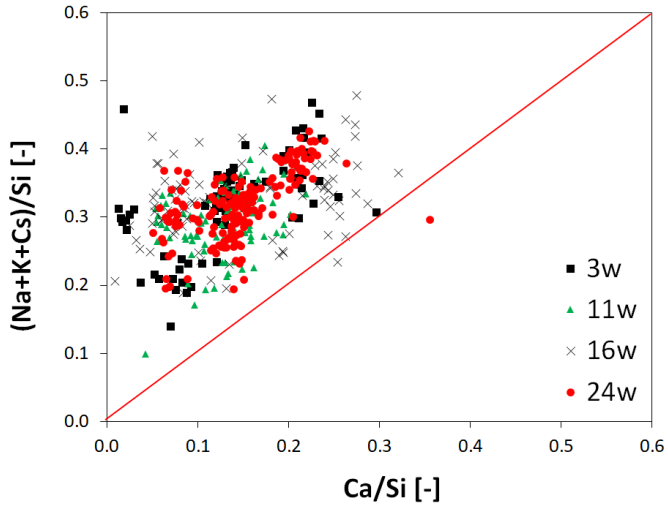


# Preliminary results

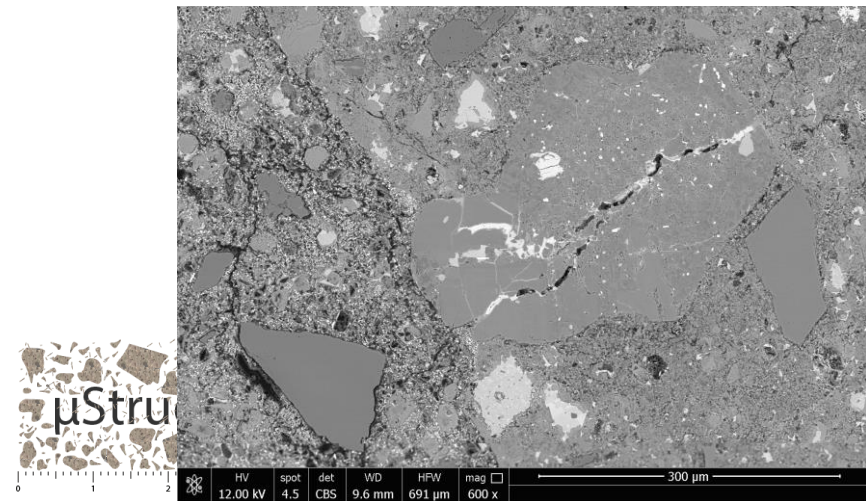
## SEM: Tx sand – conventional

Leemann et al. 2020

ASR products	Ca/Si	(N a+ K )/Si	Na/K
<i>Amourphous</i>	0.24	0.28	0.64
<i>Crystalline</i>	0.22	0.23	0.18



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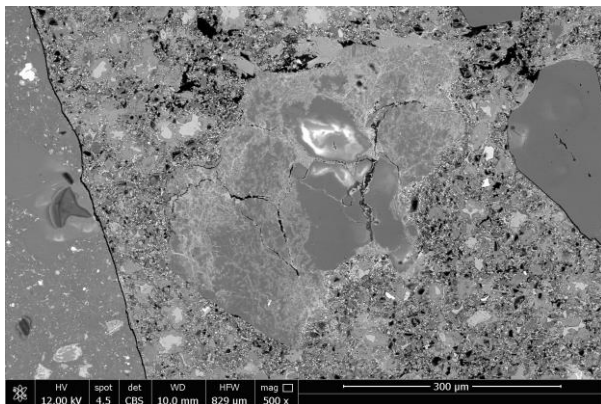


# Preliminary results

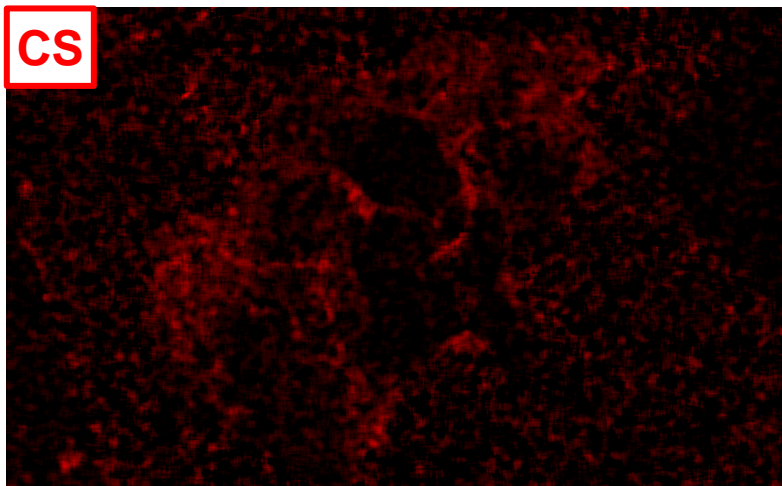
**SEM:** Tx sand - conventional (3 w)

Leemann et al. 2020

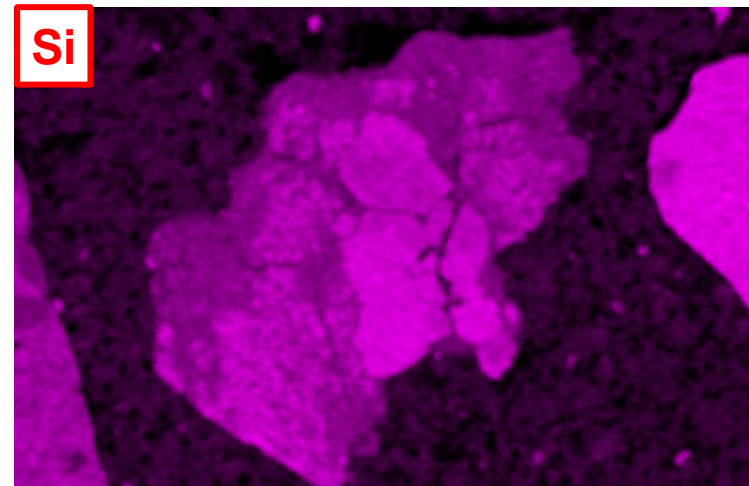
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CS



Si

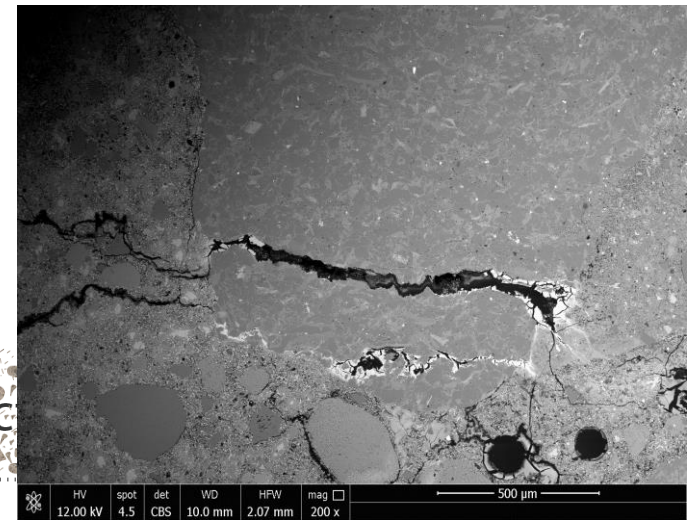
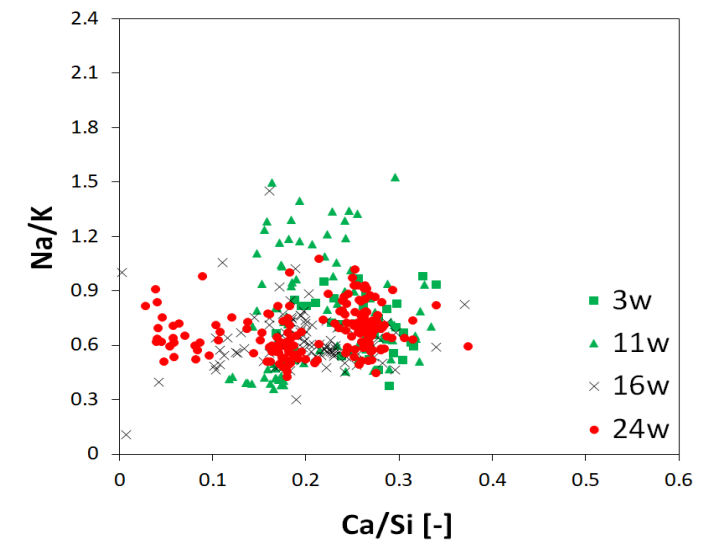
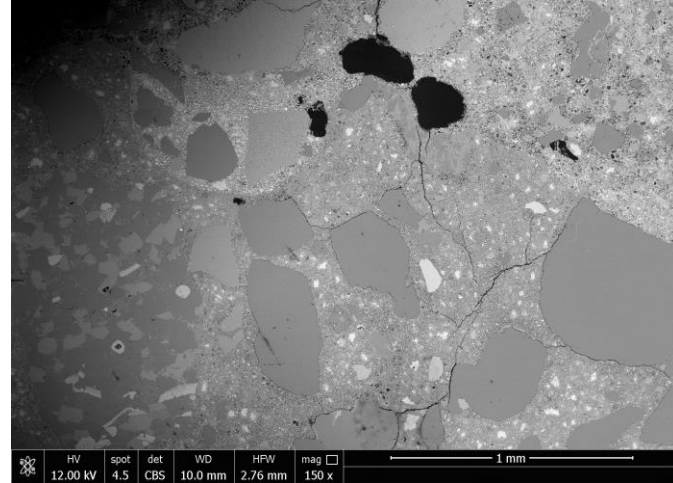
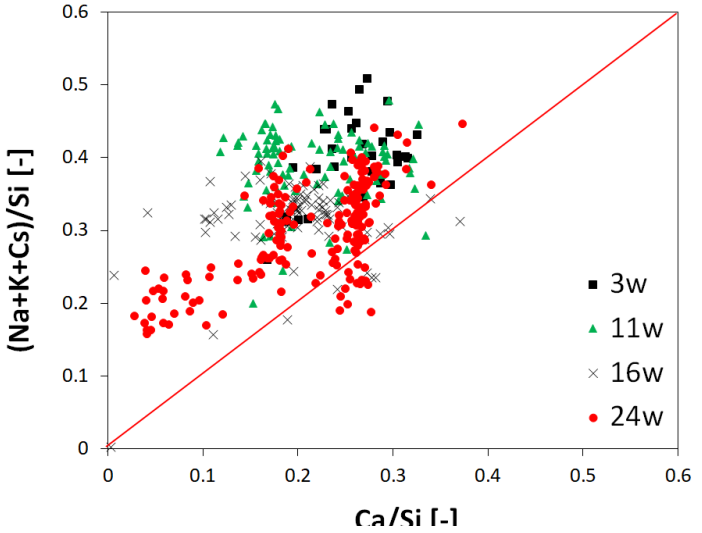


# Preliminary results

## SEM: RCA coarse SPH

Leemann et al. 2020

ASR products	Ca/Si	(N a+ K )/Si	Na/K
<i>Amourphous</i>	0.24	0.28	0.64
<i>Crystalline</i>	0.22	0.23	0.18



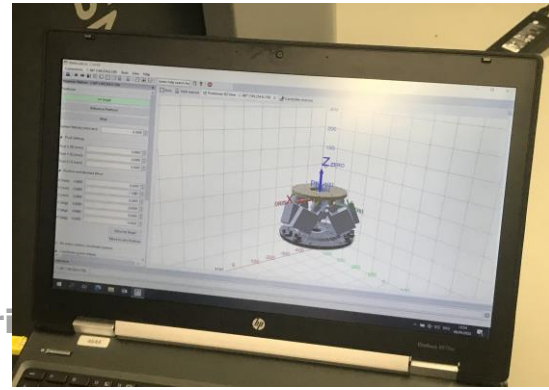
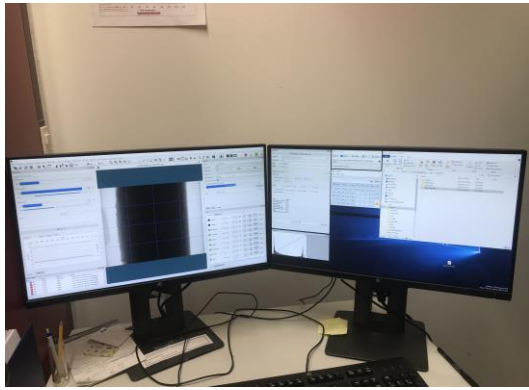
wa.ca



# Preliminary results

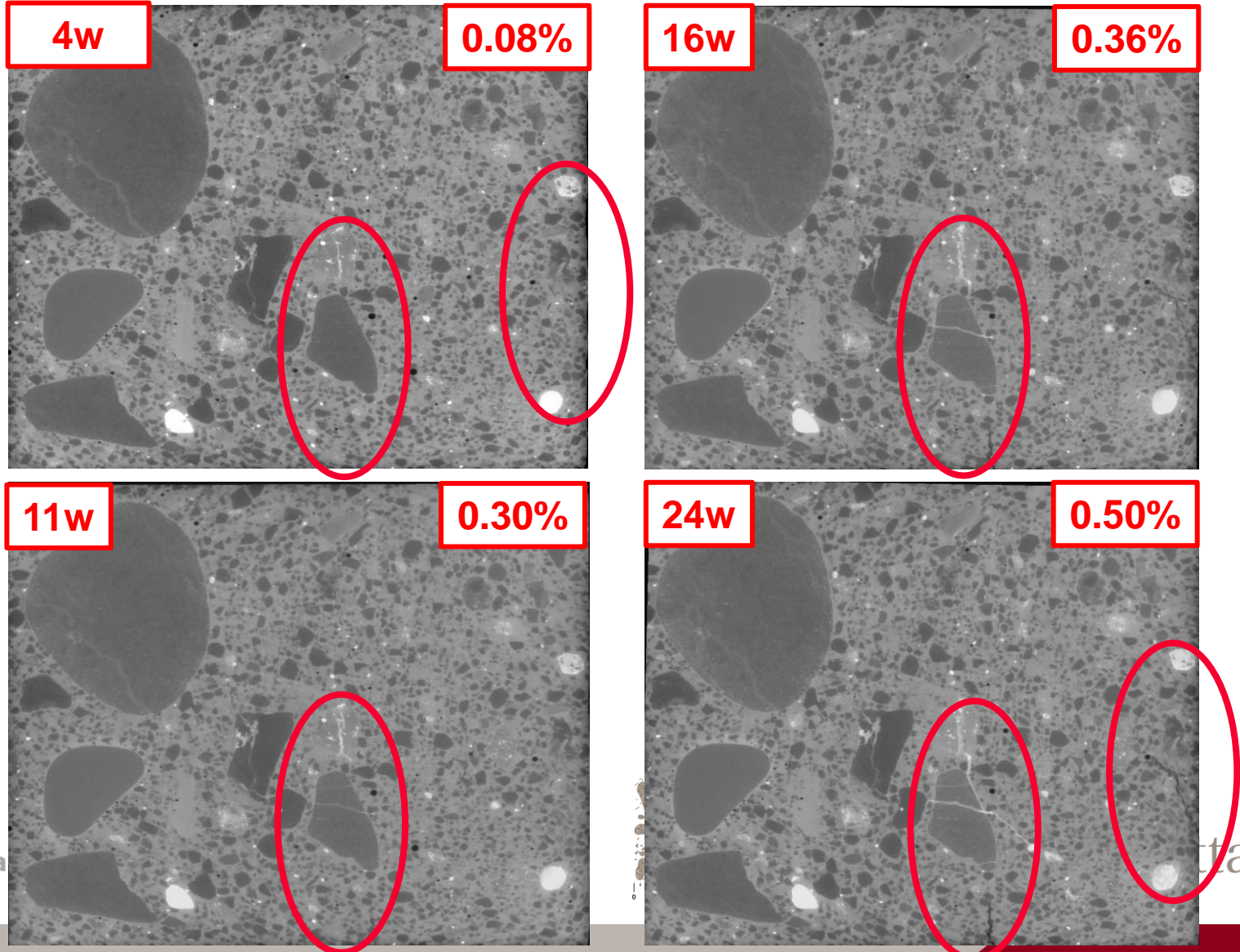
## CT Scan:

- Voxel size: 23  $\mu\text{m}$
- Effective spatial resolution: 50  $\mu\text{m}$
- Tomographic acquisition: 3600 radiographs for each tomogram (2 h acquisition time)
- Tomograms treatment:
  - *Rotation, ROI definition and cropping*
  - *Segmentation*
  - *Rendering*
  - *Noise reduction*
  - *Images registration*
  - *Computation of cracks and reaction products*



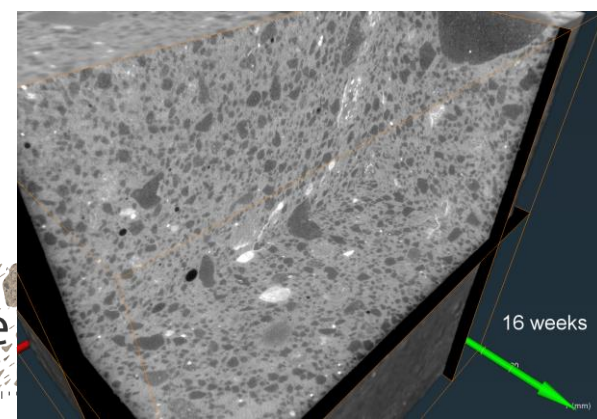
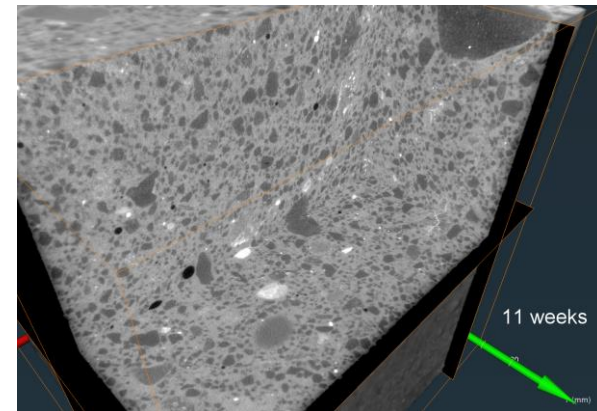
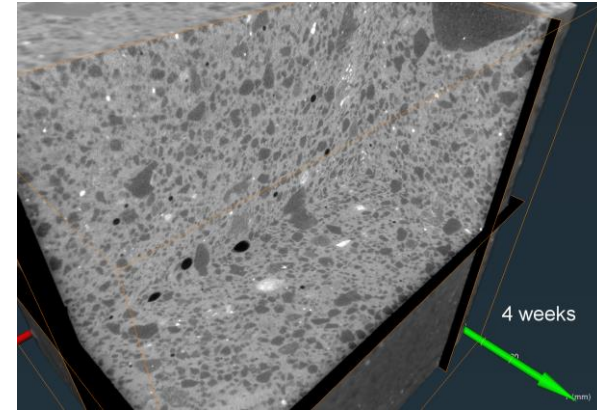
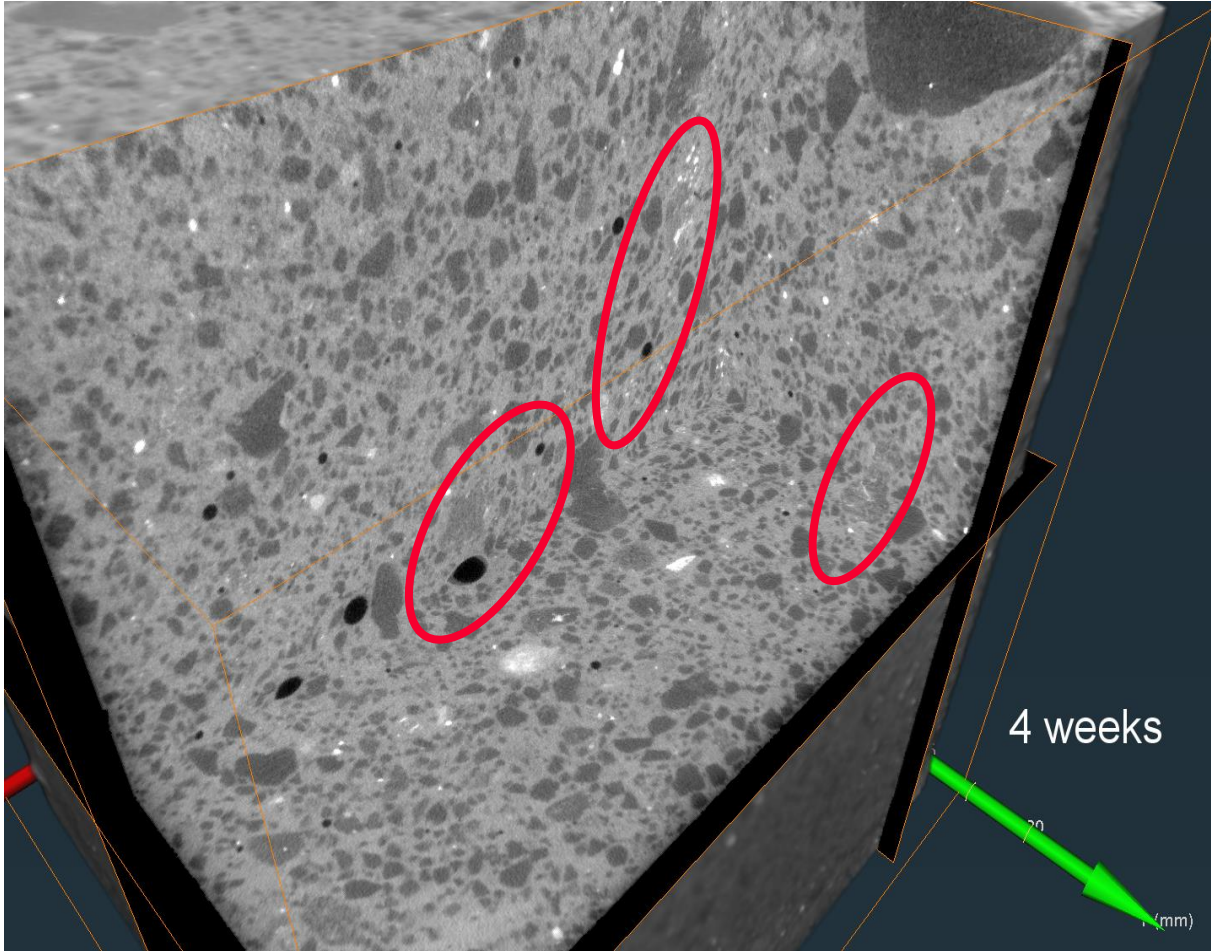
# Preliminary results

**CT scan:** Tx fine aggregate – conventional (slices)



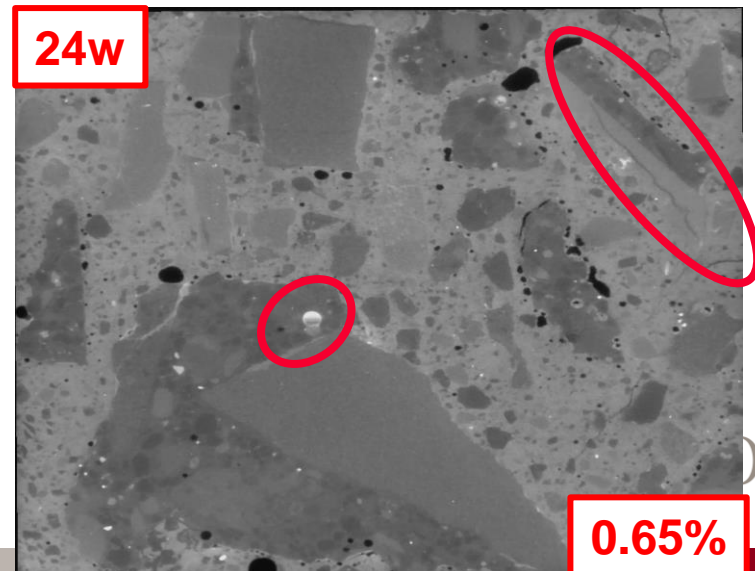
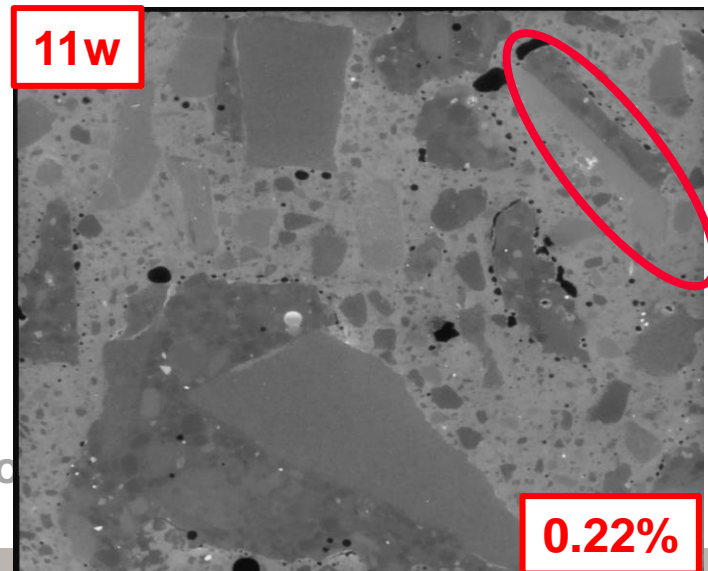
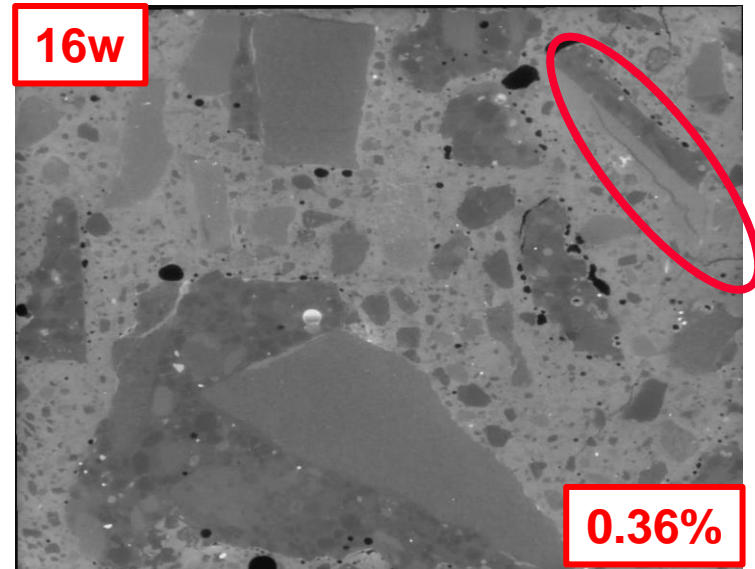
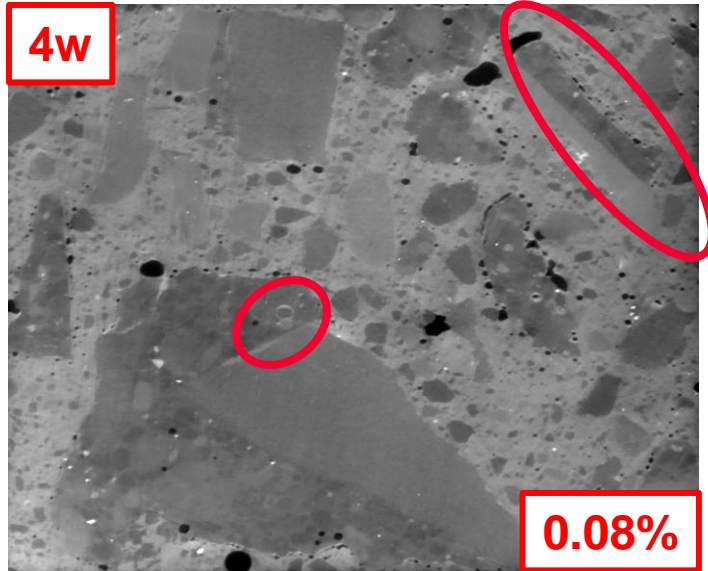
# Preliminary results

CT scan: Tx fine aggregate – conventional (rendering)

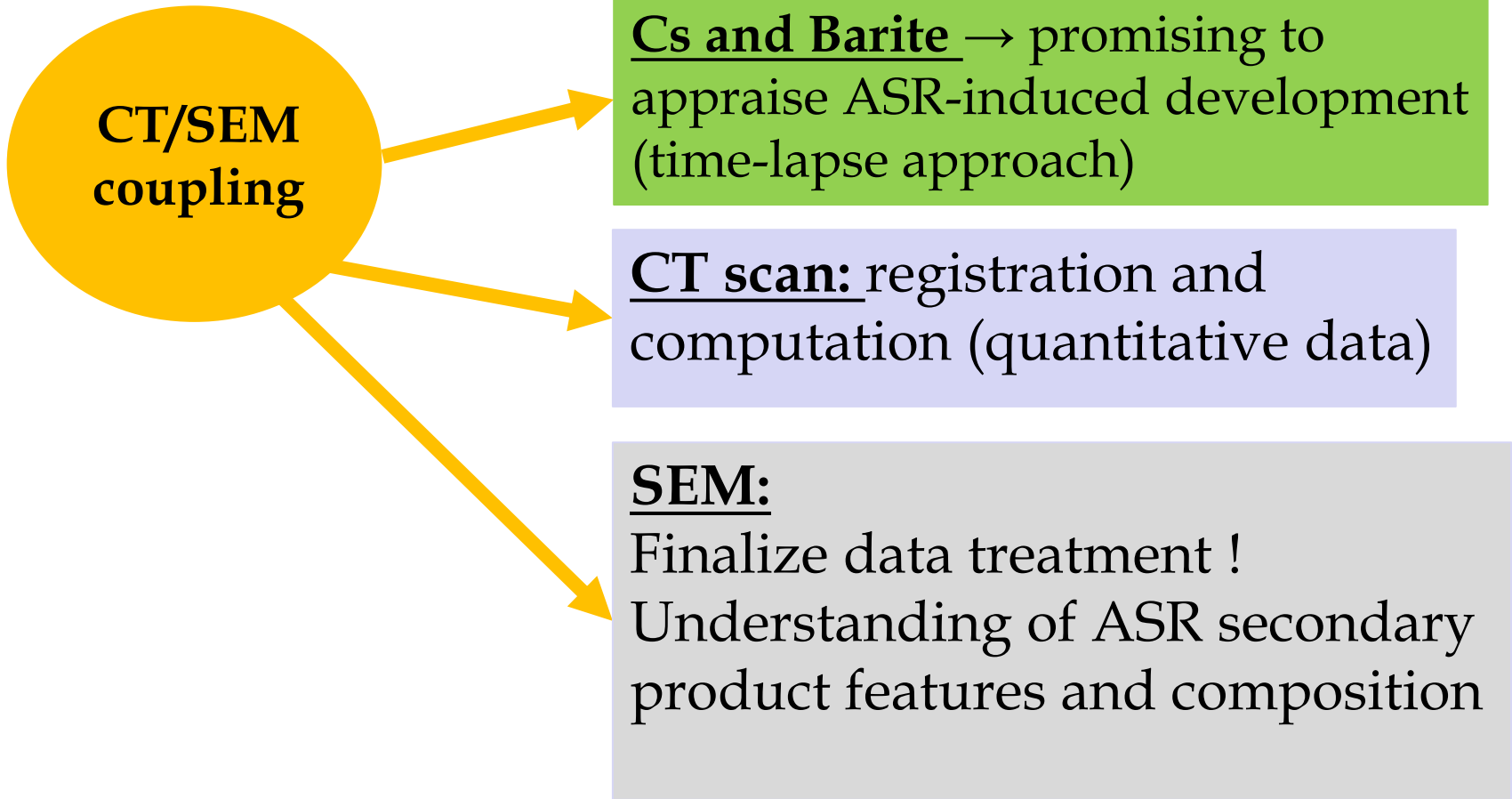


# Preliminary results

## CT scan: RCA coarse SPH



# Conclusions and Future Work



Cs and Barite → promising to appraise ASR-induced development (time-lapse approach)

CT scan: registration and computation (quantitative data)

SEM:  
Finalize data treatment !  
Understanding of ASR secondary product features and composition







**Thank you!**

**Questions?**

