MAGIC WP : CHEMO-MECHANICAL AGING OF CEMENTITIOUS MATERIALS

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4th International Symposium on Cement-Based Materials for Nuclear Wastes

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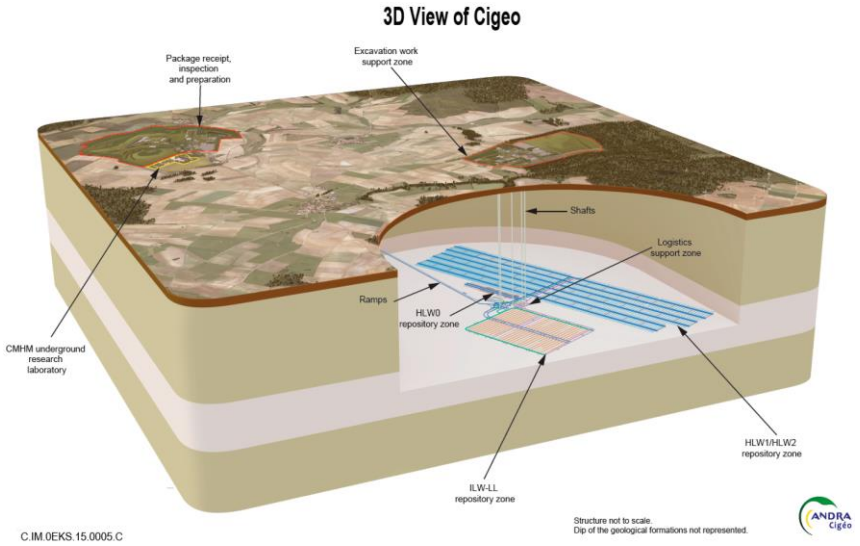
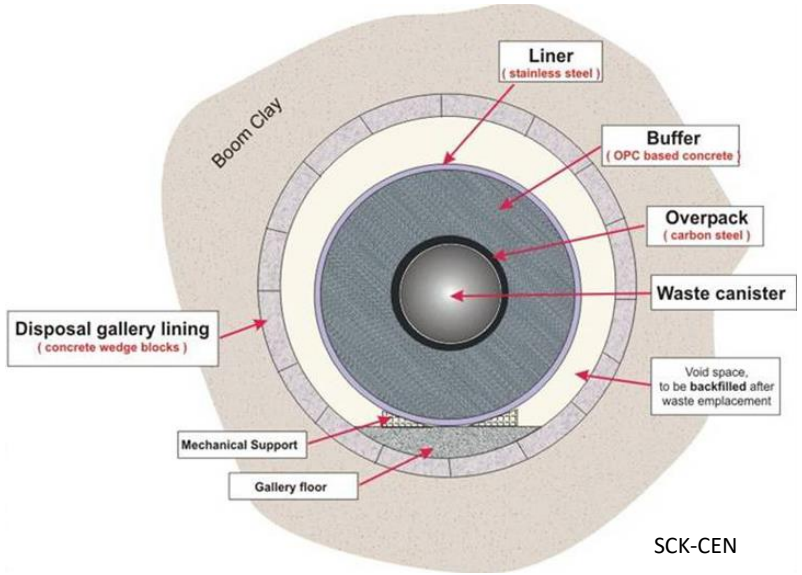
Geological disposal

Cementitious materials widely used for : - Backfill - Barrier - Massive plugs in sealing area

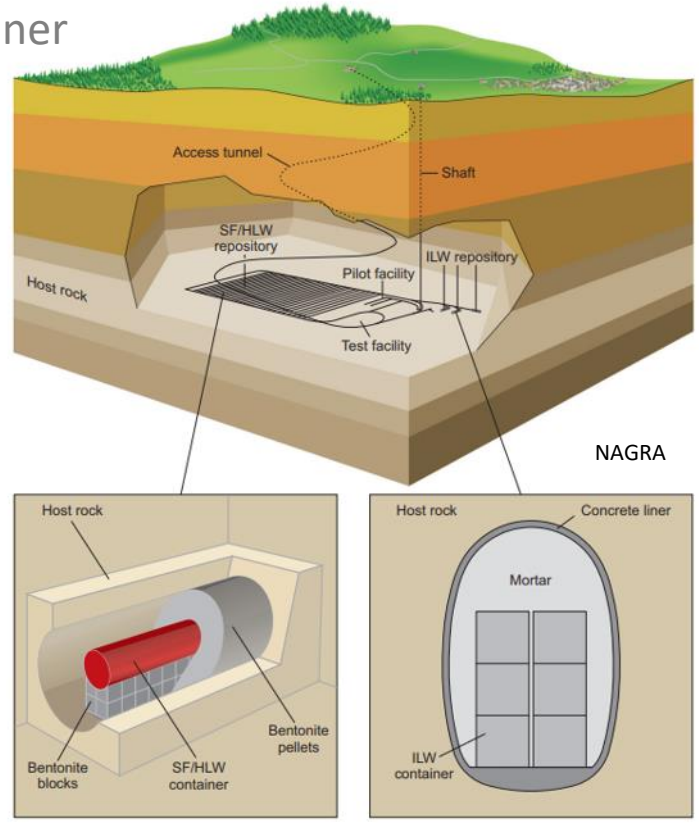
- Buffer material - Container - Vulv/liner

- Conditioning matrix





SCK-CEN



NAGRA

A use from the operating period to the long term

Material exposed to a set of disturbances

CONTEXT

Following gaps identified :

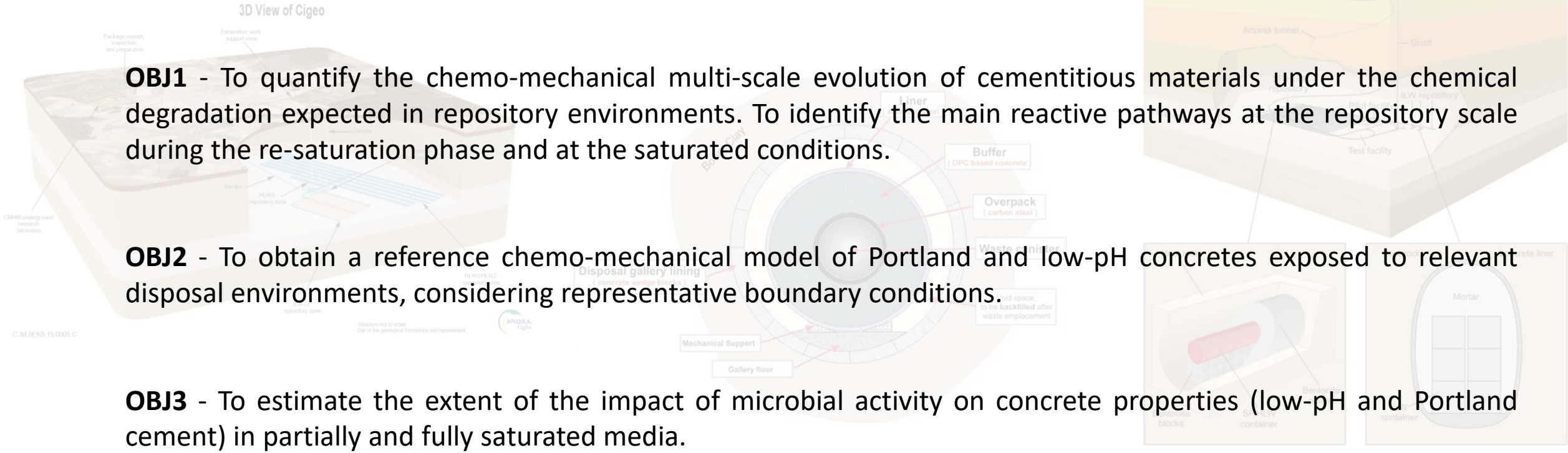
- **G1** – What is the impact of various chemical degradation phenomena on the mechanical behavior of massive cementitious materials.

- **G2** – What is the impact of microbiologically induced processes in the chemo-mechanical behavior of cementitious materials? Do these processes change the chemical evolution expected without microbiological activity?

- **G3** – How to model the long-term chemo-mechanical behavior of cementitious materials during hydraulic transients or saturated media with respect to the chemical evolution with (and without) microbial activity?

- **G4** - How to achieve comprehensive model based description of the multi-scale modelling process?

OBJECTIVES



OBJ1 - To quantify the chemo-mechanical multi-scale evolution of cementitious materials under the chemical degradation expected in repository environments. To identify the main reactive pathways at the repository scale during the re-saturation phase and at the saturated conditions.

OBJ2 - To obtain a reference chemo-mechanical model of Portland and low-pH concretes exposed to relevant disposal environments, considering representative boundary conditions.

OBJ3 - To estimate the extent of the impact of microbial activity on concrete properties (low-pH and Portland cement) in partially and fully saturated media.

THE MAGIC WP PHILOSOPHY

Structure scale

Macroscale

Mesoscale

Microscale

Nanoscale

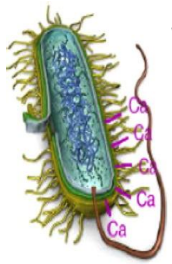
CHEMICAL EVOLUTION

MECHANICAL BEHAVIOUR

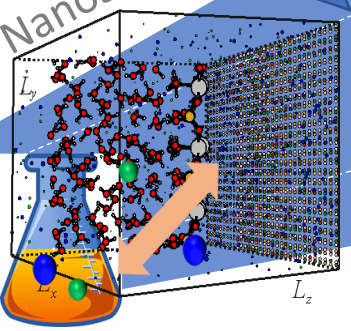
MICROBIAL IMPACT

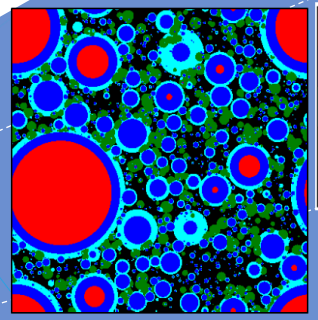
Experiment

Modelling

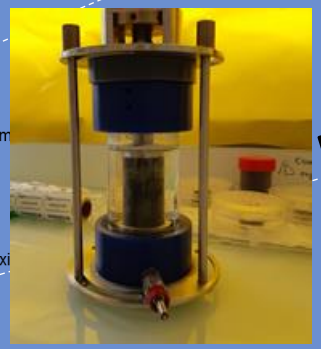


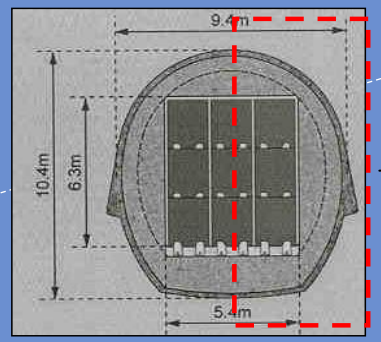
Vijay et al. 2017

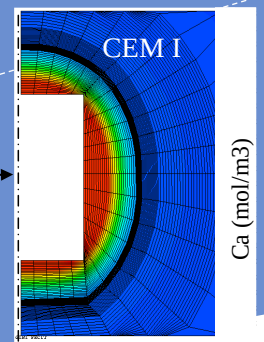




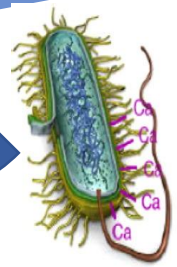
Microscale
<10^{-6} m







Sellier et al. 2011



Vijay et al. 2017

WP STRUCTURE

Task and WP Leader : **IRSN (TSO)**

TASK 1
Strategy and piloting the WP SOTA and dissemination

- ST1-1: WP coordination
- ST1-2: State of the Art
- ST1-3: Training materials
- ST1-4: Analysis of experiments and numerical models

Task Leader : **ANDRA (WMO)**

TASK 2
Chemo-Mechanical evolution of cementitious materials at the meso/macroscale

- Task 2-1: Chemo - Mechanical evolution of unsaturated concrete
- Task 2-2: Chemo - Mechanical evolution of saturated concrete
- Task 2-3: Microbial impact on chemo-mechanical evolution of concrete

Task Leader : **UFZ (LTP FZJ)**

TASK 4
Modelling of the chemo-mechanical evolution of cementitious materials in disposal environments

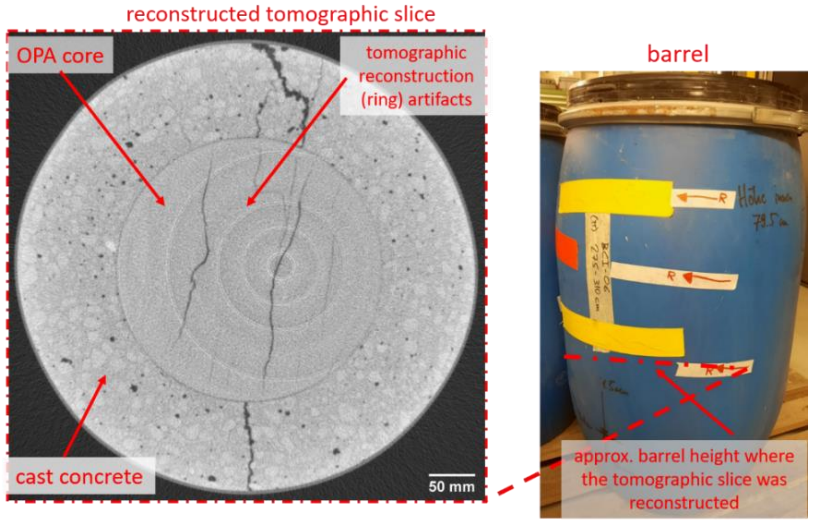
- ST4-1. Chemo-mechanical numerical coupling development at micro-scale
- ST4-2. Upscaling methods from nano to micro to REV
- ST4-3. Chemo-mechanical processes in safety structures

Task Leader : **PSI (RE)**

TASK 3
Chemo-Mechanical evolution of cementitious materials at the nano/microscale

- SubTask 3.4: Conceptualization of data and models parameters
- SubTask 3.1: 3D Microstructure & Mechanical characterization
- SubTask 3.2: 2D &3D Microstructure modelling (MBC)
- SubTask 3.3: 2D Bio-Chemo-Mechanical characterization

TASK 2 – CHEMO-MECHANICAL EVOLUTION OF CEMENTITIOUS MATERIALS EXPOSED TO DEEP DISPOSAL ENVIRONMENT AT THE MESO-MACRO SCALE



Carbonation

Monitoring or testing buried or drilled existing samples from ongoing experiments

Chemo-mechanical stability of concrete Vs microbial activity under aerobic & anaerobic conditions

Corrosion on reinforced structures

Multi-ionic attacks

Degradation scenarios on a structural behavior level

Microbial impact-Behavior of a low-pH under repository-like conditions - operational phase

TASK 2 DESCRIPTION – EXPERIMENTAL TASK (MESO-MACROSCALE)

Coordination team: Mechanics : **ANDRA (Task leader) ;** Chemistry**: COVRA;** Microbiology **: HZDR**

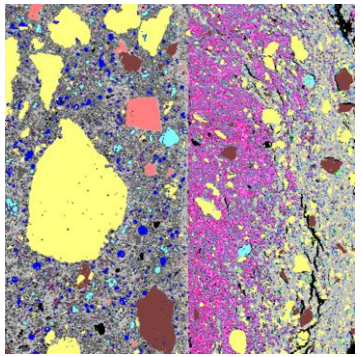
Objective: to study the chemo-mechanical behaviour at the macro scale taking into account the cement/aggregate structural behaviour.

Focus on experimental studies: a set of on-going and new experiments with a selection of mortar/concrete samples in contact with various solutions/rocks and atmospheres (CO_2) (+ impact of rebar corrosion). Representative of different host rocks, with or without microbial activity.

Experimental setup for the triaxial (left) and creep tests (right)
Ecole centrale des Mines

To identify the chemical/textural changes

→ impact on mechanical properties (Young modulus, compressive/tensile strengths, creep…).

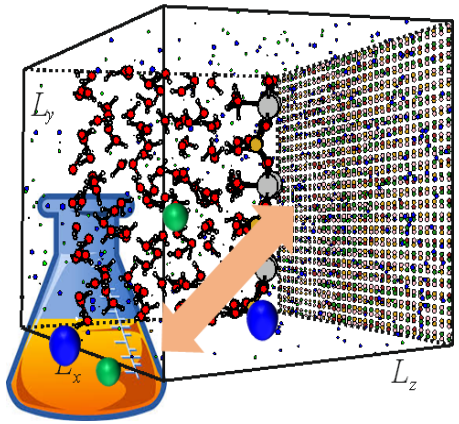


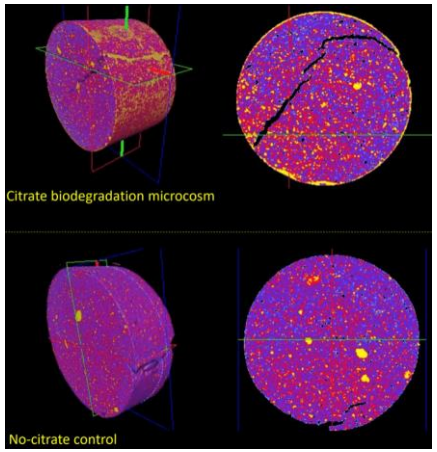
Coupled leaching – carbonation at concrete – clay interface

Rebars corrosion and mechanical damage on concrete

Chemo-hydro-mechanical modelling from the sample scale to the structure scale (Task 4) .

TASK 3 – CHEMO-MECHANICAL EVOLUTION OF CEMENTITIOUS MATERIALS EXPOSED TO DEEP DISPOSAL ENVIRONMENT AT THE NANO-MICRO SCALE





3D characterization of microstructure

Chemical impact

Mechanical tests

Microbial effect

Integration in modelling at micro and nano scale

CMB evolution → up-scaling

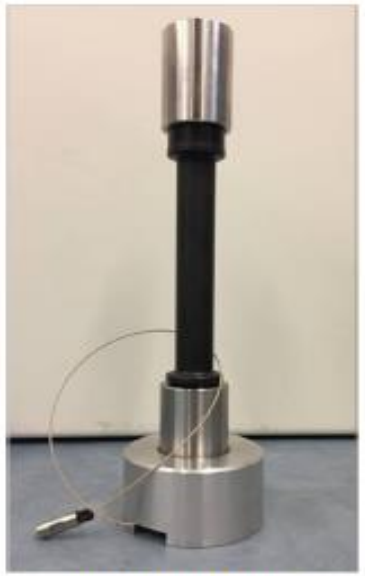
Bridges between multi-scale experiments and modelling

TASK 3 DESCRIPTION – NANO-MICROSCALE

Coordination team: Chemistry : **PSI (Task leader) ;** Mechanics : **LAMcube ;** Microbiology : **SCK**

Objective and approaches

ST3-1



(a) In-situ triaxial test device

3D characterization of microstructural degradation by chemical attacks at the pertinent scale

Mechanical tests at microscopic and nanoscopic scale

ST3-4

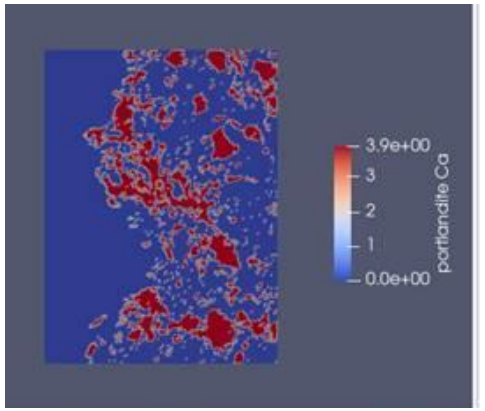
Quantify the relationships between μstructural changes and macroscopic behaviour evolutions

→bridge between multi-scale experiments and modelling → T4

Bridge the time and special resolution between in-situ charact. of μtructure and pore scale modelling

Integration of microbial effect into pore scale microstructure modelling

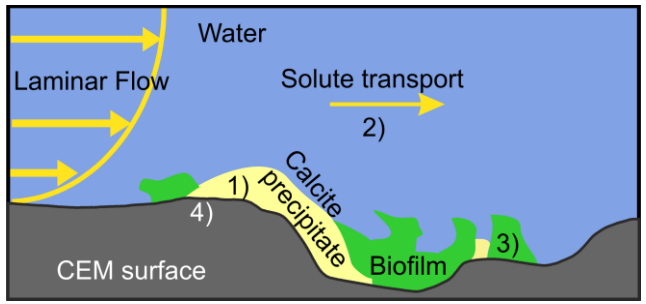
Upscaling



ST3-2

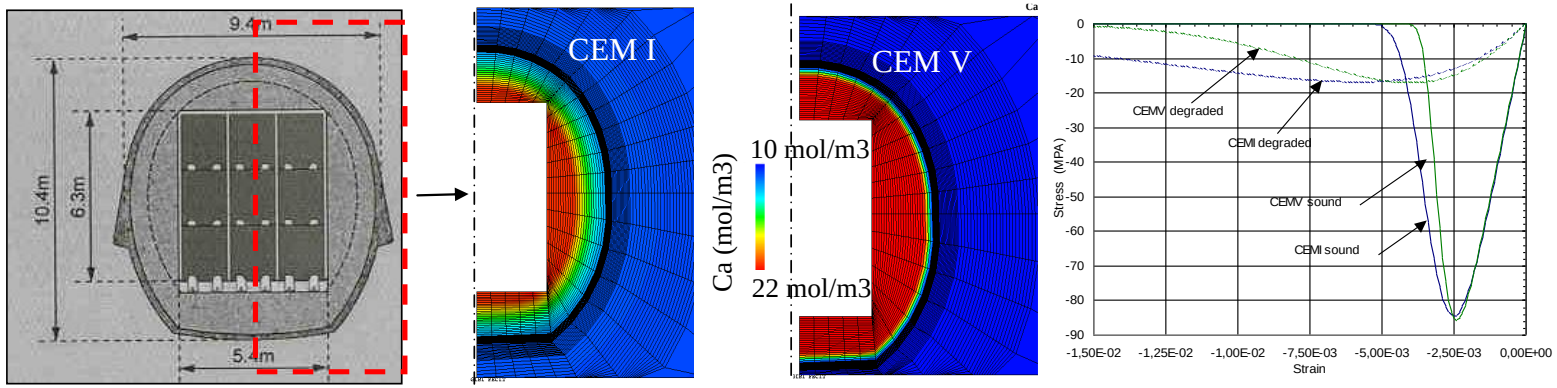
ST3-3

Quantification of the microbial influence on chemo-mechanical behaviour



Establish the bridge between the Bio-Chemo-Mechan. as well as the link to the modelling

TASK 4 – MODELLING OF THE CHEMO-MECHANICAL EVOLUTIONS OF CEMENTITIOUS MATERIALS IN DISPOSAL ENVIRONMENTS

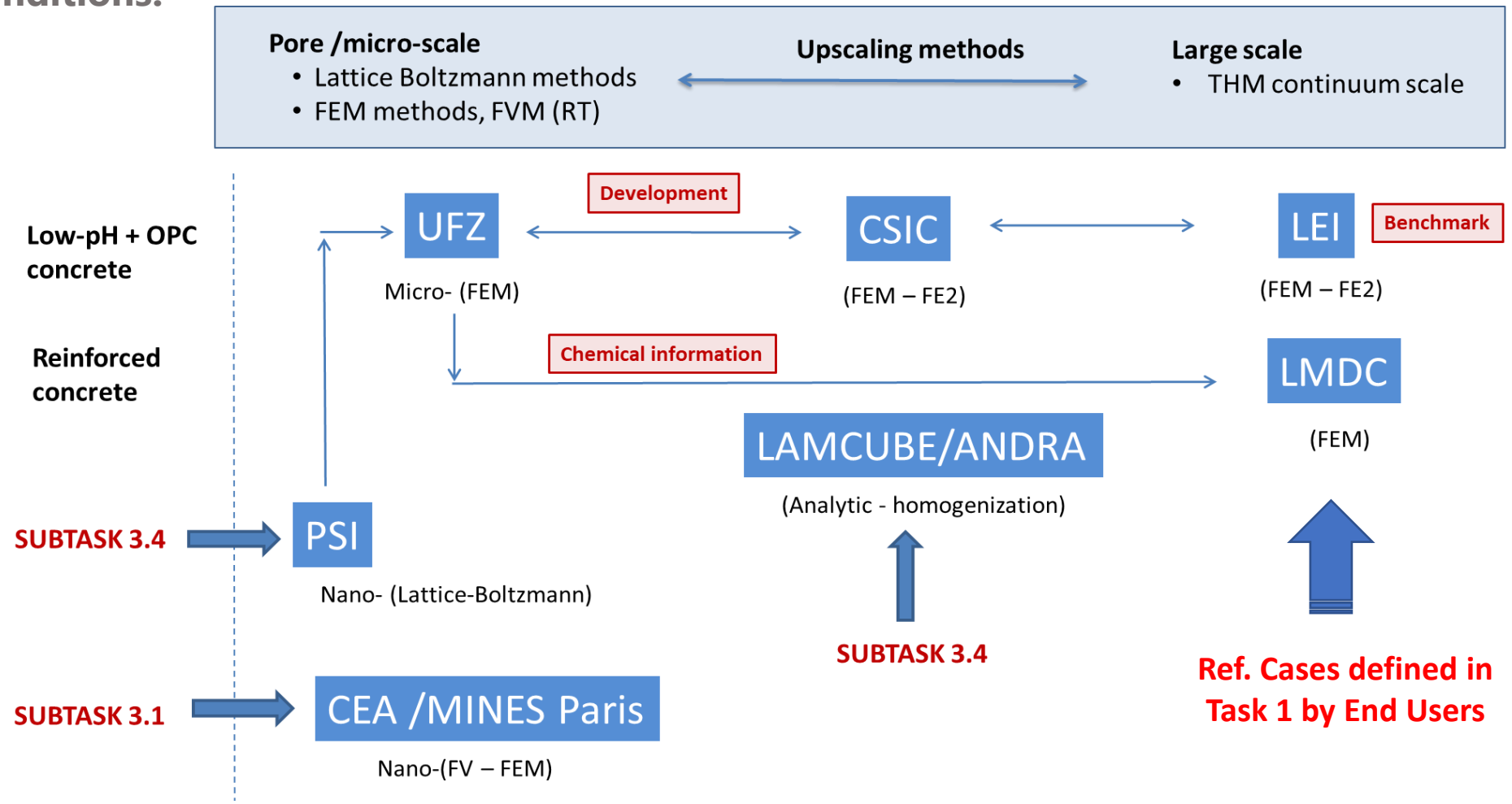


- Chemo mechanical modelling
- Code development
- Multiscale modelling
- Integration of experimental results
- Carbonation
- Multi ionic attack
- Structure scale modelling
- Lattice-Boltzmann
- Finite Element

TASK 4 DESCRIPTION – INTEGRATIVE TASK

Coordination team: Task leader : **UFZ ;** Subtask leader : **LMDC**

Objective: To obtain long-term reference chemo-mechanical models of Portland and low-pH concrete degradation exposed to relevant disposal environments, considering representative boundary conditions.



EXPECTED OUTCOMES

- **1-** To obtain a multiscale experimental dataset → link between the chemical degradation under coupled representative disturbances and the mechanical parameters: compressive, tensile strengths, Young modulus evolution, cracks formation and their dynamics of extension…

- **2-** To identify the main reactive mechanisms → consequences on the mechanical behaviour of Low-pH and Portland cement with and without the microbial impact.

- **3-** To develop model on the mechanical behaviour under chemical evolution at the experimental scale.

- **4-** To determine a material mechanical behaviour law considering the chemical and hydrodynamical evolutions and processes at different scale.

- **5-** To model the long-term mechanical evolution of concrete structure exposed to disposal conditions due to chemical disturbances (including microbial impact).

PARTNERS AND BUDGET

- 26 partners (8 RE, 4 WMO, 3 TSO, 11 LTP) + 1 additional End User
- From 10 member states
- Project duration : June 2021 – May 2024
- Total budget : 4.285 M€

WMO	RE	TSO	LTP	E.U.
ANDRA	U. Helsinki	IRSN	Manchester	NAGRA
COVRA	FZJ	CIEMAT	LMDC	
SURAO	CEA	GRS	UGR	
RWM	LEI		UFZ	
	PSI		EMPA	
	SCK-CEN		Mines Paris Tech	
	LAMCUBE (CNRS)		HZDR	
	CVR		CTU	
			UJV	
			TUL	
			CSIC	

THANK YOU FOR YOUR ATTENTION

A WP to support knowledge development on chemo-mechanical aging of cementitious material, by crossing specialists from chemistry, mechanics and microbiology following an upscaling process.

For more information : alexandre.dauzeres@irsn.fr