

# DOPAS Training Workshop 2015

Learning Unit 3 : Design of a seal for an experiment/demonstrator within the broader context of RD&D programs

Safety assessment and performance assessment of closure as design input

How to move from initial design in an iterative manner to the final experiment design and construction (to as build) and assess the outcome

The use of individual tests to complement existing material and process knowledge (case of REM metric experiment)

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D3 3.2.1 16 September 2015

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## Summary

Background and context

Aims of the experiment

Experimental layout

First results

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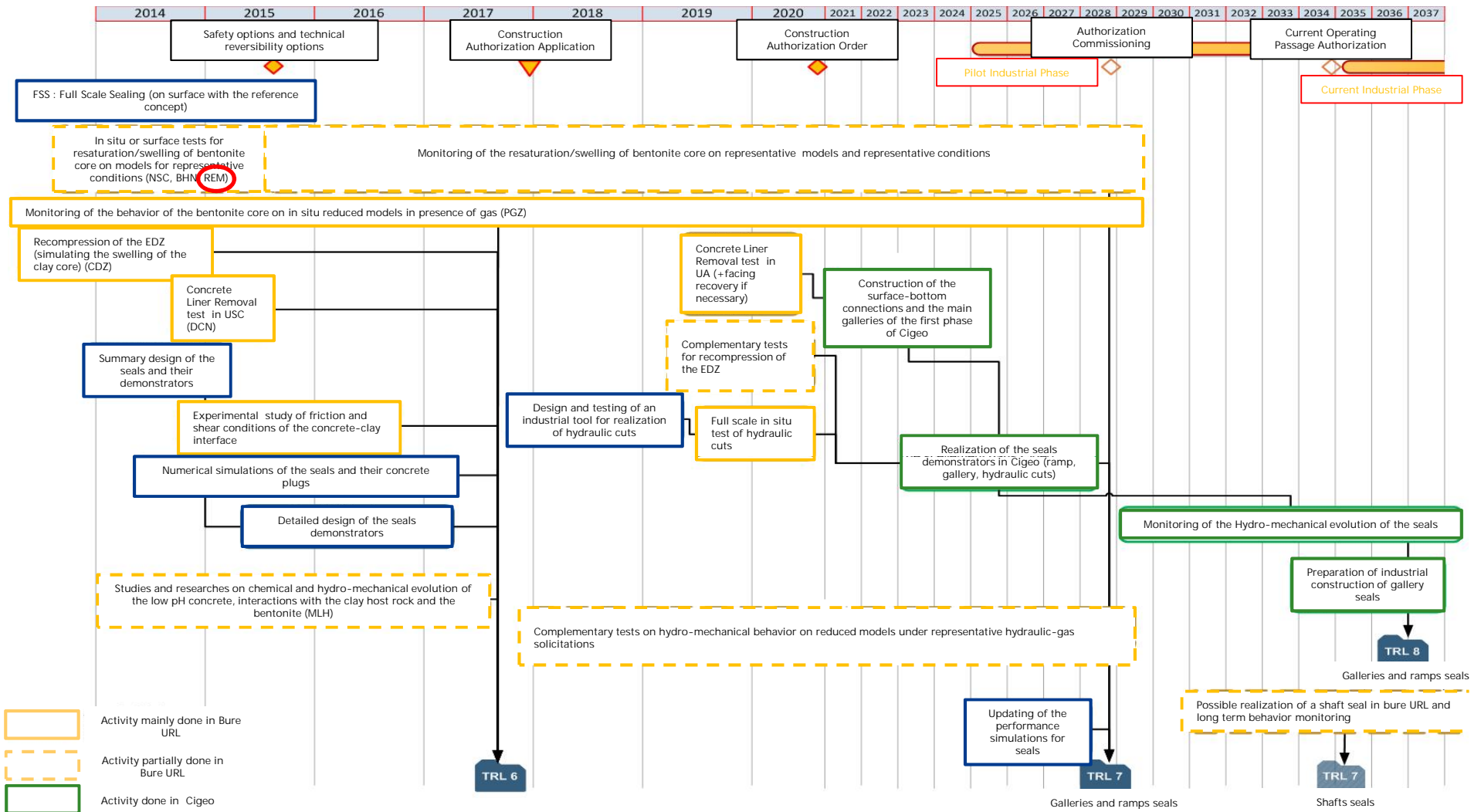
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# Background and Context (1/2)

## Cigéo 2015-2035 PDP



## Background and Context (2/2)

### Plugs and seals demonstrator program

#### » Technical feasibility

##### □ Surface demonstrators

+ FSS "Scale one technical feasibility for a drift plug" (DOPAS WP3)

- » Test of concrete formulations
- » Test of pellets/powder bentonite formulation
- » Test of filling of the plug by the bentonite mixture

+ TSS and SET "hydraulic cut-offs"

- » Test of filling the hydraulic cut-offs with bentonite blocks

##### □ Underground demonstrators (Bure URL)

+ DCN "removal of tunnel lining segments"

+ BHN "natural resaturation at metric scale"

#### » Phenomenological understanding consolidation

##### □ Surface demonstrators

+ REM "metric scale resaturation" test (DOPAS WP5)

- » FSS pellets/powder mixture
- » Near to natural resaturation

##### □ Underground demonstrators (Bure URL)

+ NSC "1/2 scale grift plug"

- » Bentonite blocks
- » Artificial resaturation

Blocks

Pellets  
and  
powder

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# REM : aims of the experiment

Complete the database on powder / pellets mixture resaturation

- » Most experiment done with forced resaturation (flow several orders of magnitude higher than in natural media)
- » At decimetric scales

Ä Metric scale experiment with “as near as possible from site” resaturation  
Same density as for FSS

Consolidate the physical representation of the HM behavior of powder/pellets mixture

- » Improve the numerical representation of the rheological behavior of such a mixture
- » Improve the numerical representation of the hydraulic behavior of such a mixture

Ä Implementation of a high number of HM sensors (not possible in-situ)  
Numerical HM simulation / benchmarking

Help provide (partial) demonstration of powder mixture “natural” resaturation for the DAC (2017)

Help design (and optimize) the seals and plugs for the Cigéo project

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Relative humidity sensor

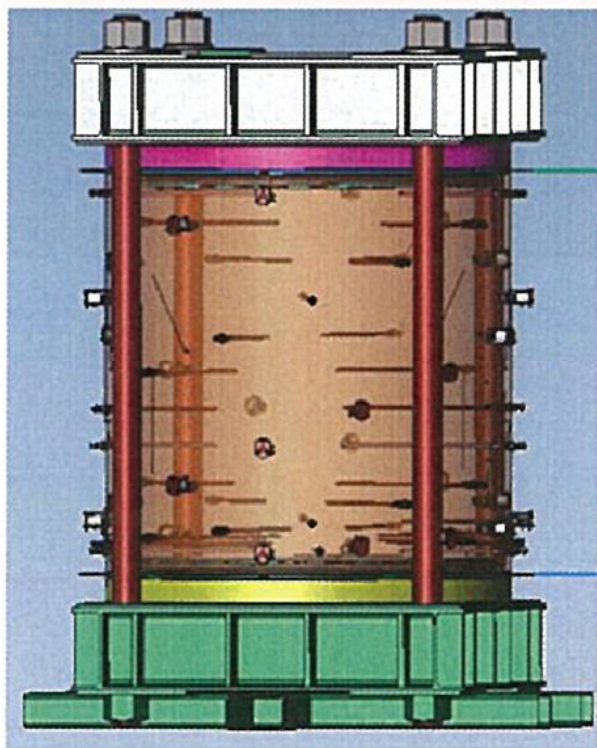
Gas flow meter 0-0,035 ml/min

Alim 24 V  
Sortie ANA 4-20mA

- Cavity test :
- cylinder
  - 1 m height
  - 1 m diameter

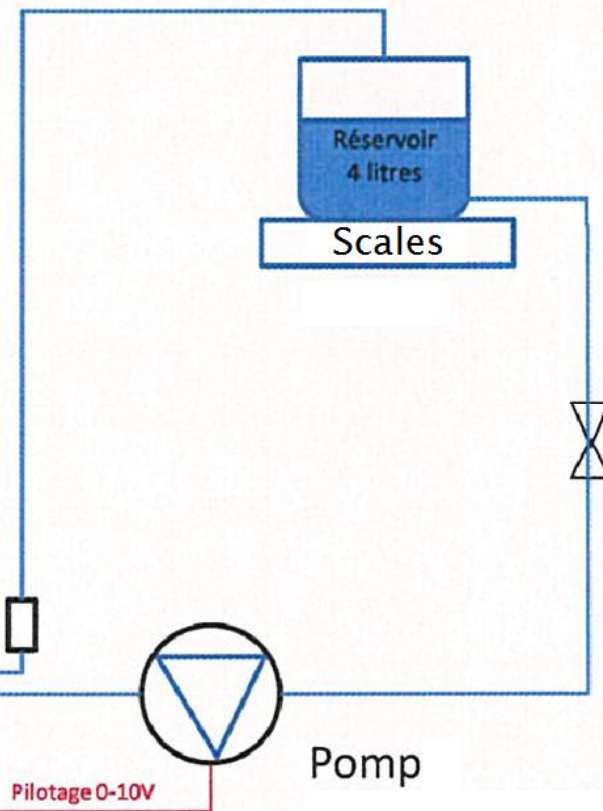
Gas outflow

# REM : experimental layout (1/5)



Resaturation from the bottom with site water

*Expected total resaturation time : 20-30 years*



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Water flow meter 2,1 g/h



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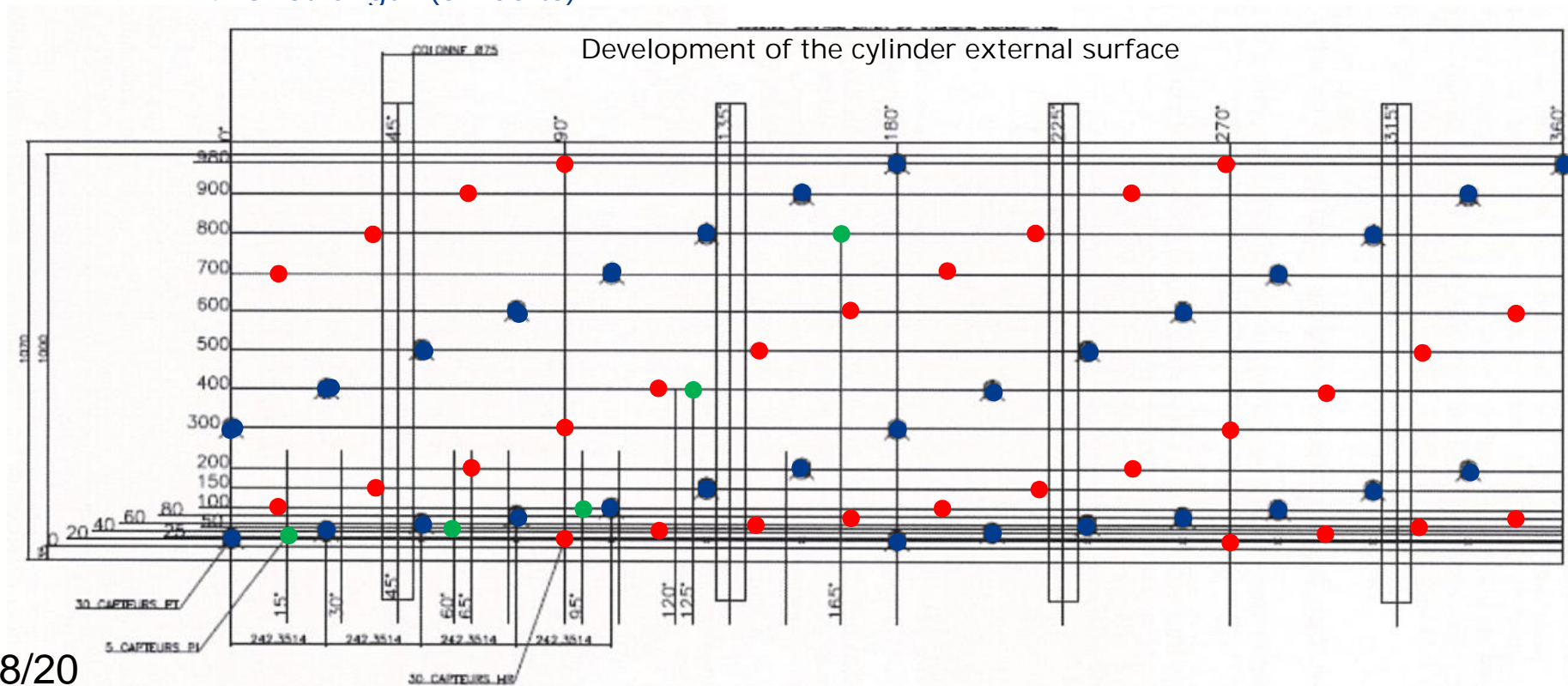


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# REM : experimental layout (2/5)

## Sensors

- » 30 for total (swelling) pressure (+ 4 on top) ●
- » 30 for relative humidity ●
- » 5 for interstitial (water) pressure ●
- » 4 for strength (on bolts) ●



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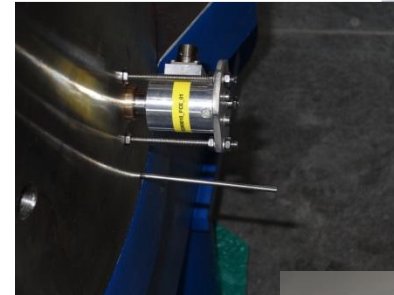


# REM : experimental layout (3/5)

## REM emplacement and filling (Sept. 2014)

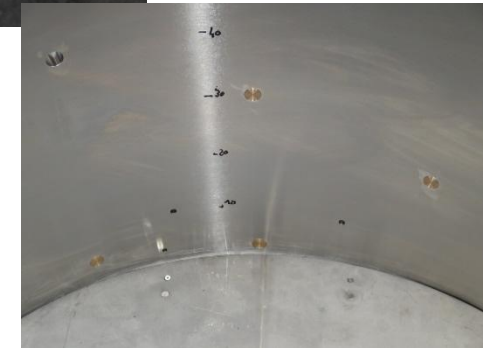
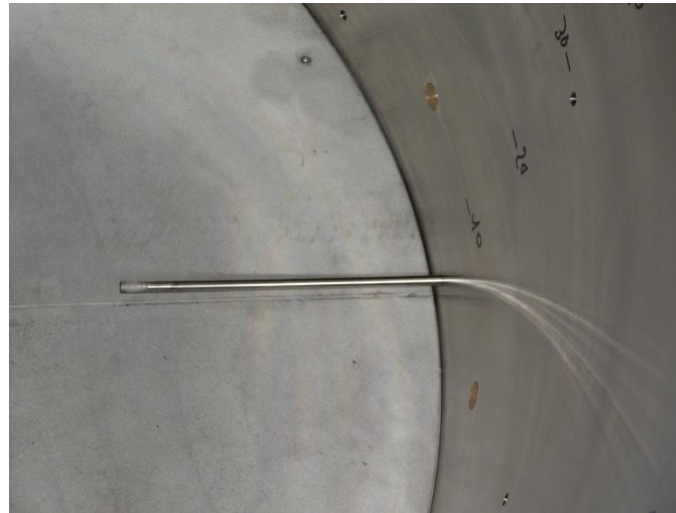


View of the test cavity during its cleaning



Total pressure sensors

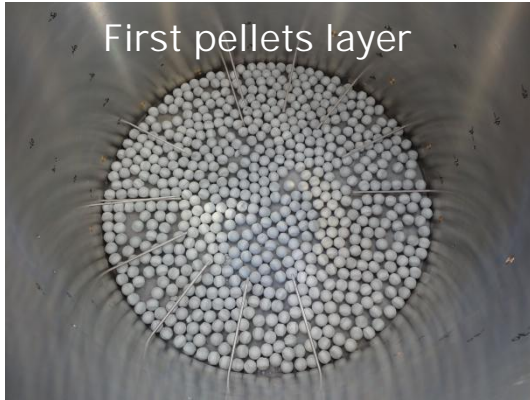
Relative humidity sensor installed



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# REM : experimental layout (4/5)

## REM emplacement and filling (Sept. 2014)



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# REM : experimental layout (5/5)

Satellite experiments ( $\varnothing$  57 mm and  $\varnothing$  240 mm cells)

» Resaturation with leached concrete water

- "Portland type" leached concrete water
- Low pH concrete water (the same as the one used for FSS)

» Measure of swelling pressure

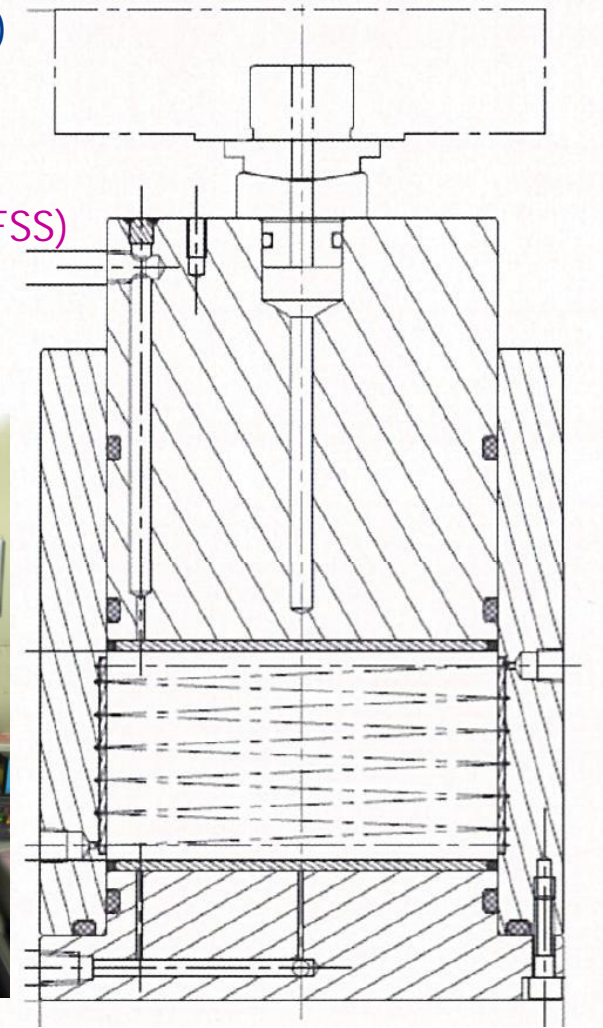
- Radial resaturation

» Measure of permeability

- Radial resaturation
- Axial permeability measurement

» Expected resaturation time

- $< 100$  d for  $\varnothing$  57 mm cell
- $< 500$  d for  $\varnothing$  240 mm cell



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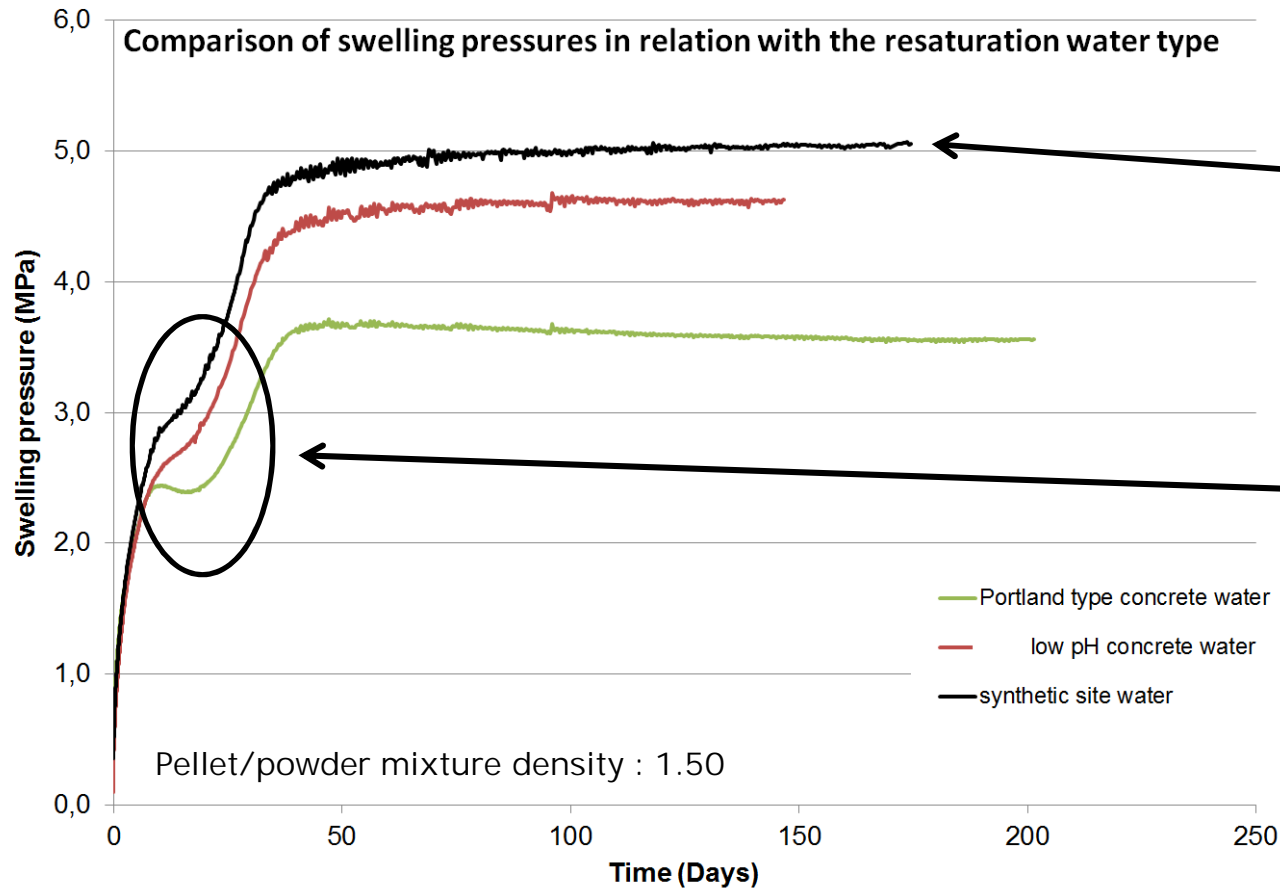
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# REM : on-going work and first results

Satellite experiment : swelling pressure in relation with different resaturation water type  
 Ø 57 mm cell



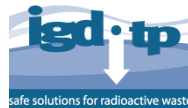
Swelling pressure higher than expected from the ESDRED (Euratom FP6) results, mainly linked to the very low water content of the bentonite used to generate the pellets/powder

With site water (and to a lesser extent with low pH concrete water) the « double porosity » behavior is not present during the resaturation phase

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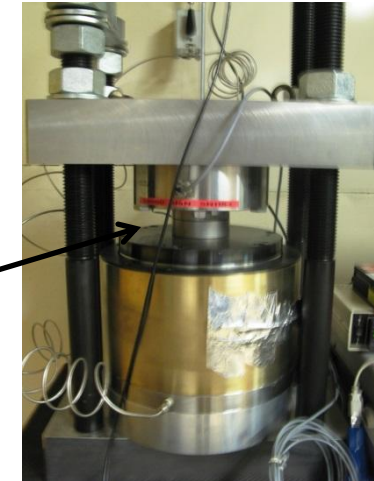
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# REM : ongoing work and first results

## Satellite experiment : Ø 240 mm cell

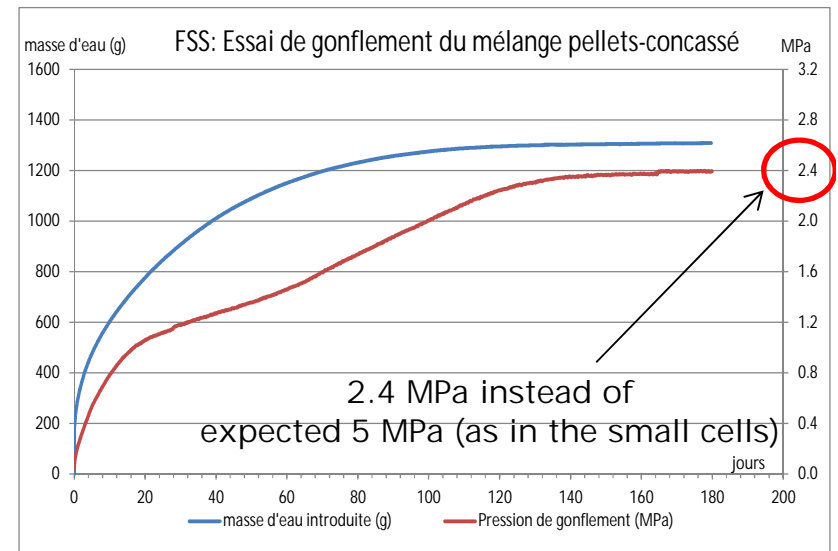
### » First used to determine the swelling pressure for FSS

- ❑ Beginning of resaturation end of April 2014
- ❑ Expected swelling pressure not reached
- ❑ The piston was stuck
- ❑ Repair of the piston (end of September 2014)
- ❑ Beginning of new experiment (October 2014)
- ❑ New swelling pressure results for FSS (February 2015)



### » Use for REM (4 to 5 month delay)

- ❑ Installation of sensors to measure (March 2015)
  - + total pressure
  - + Relative humidity
- ❑ Beginning of experiment (March 2015)
- ❑ Results obtained in July 2015 : swelling pressure of around 3.3 MPa
- ❑ Density of the bentonite pellets/powder mixture was not exactly the same as the one used for the small diameter cell



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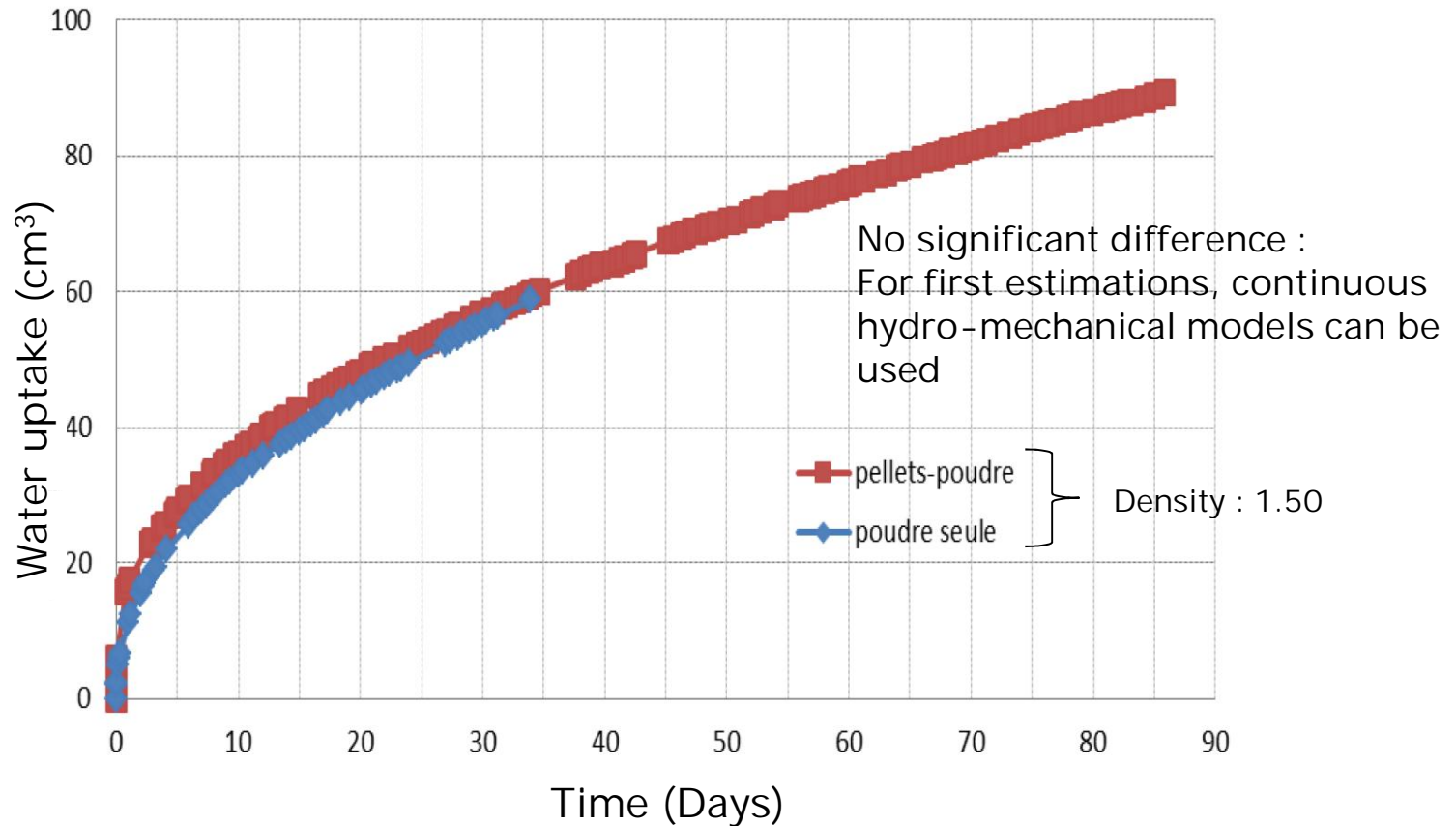
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# REM : ongoing work and first results

Satellite experiment : water uptake for powder and pellets/powder mixture

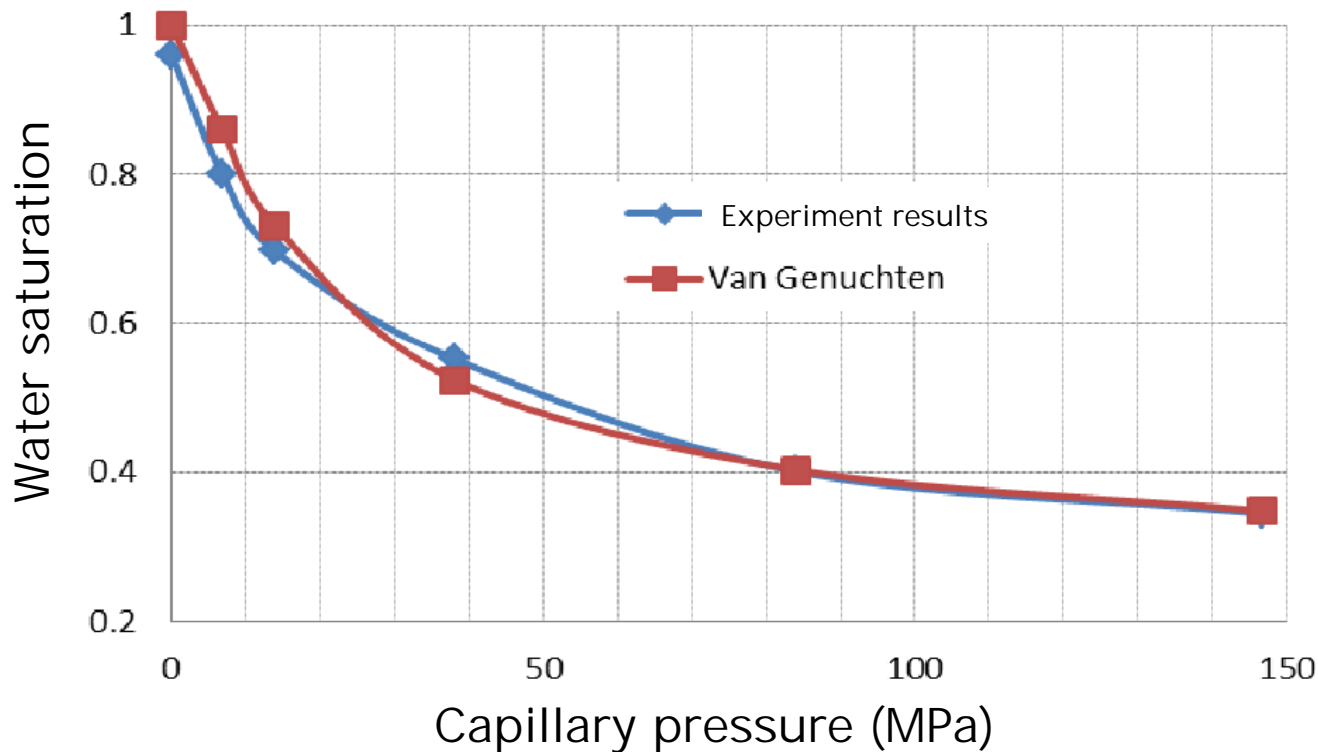


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# REM : ongoing work and first results

REM first hydraulic (no mechanic) numerical simulation

Van-Genuchten retention curve calibration



$$S_{r,w} = S_{res} + \frac{S_{max} - S_{res}}{\left[1 + \left(\frac{P_{cap}}{P_r}\right)^n\right]^m}$$

$$S_{max} = 1$$

$$S_{res} = 0.25$$

$$m = 0.486085$$

$$n = 1.88$$

$$P_r = 14 \times 10^6 \text{ Pa}$$

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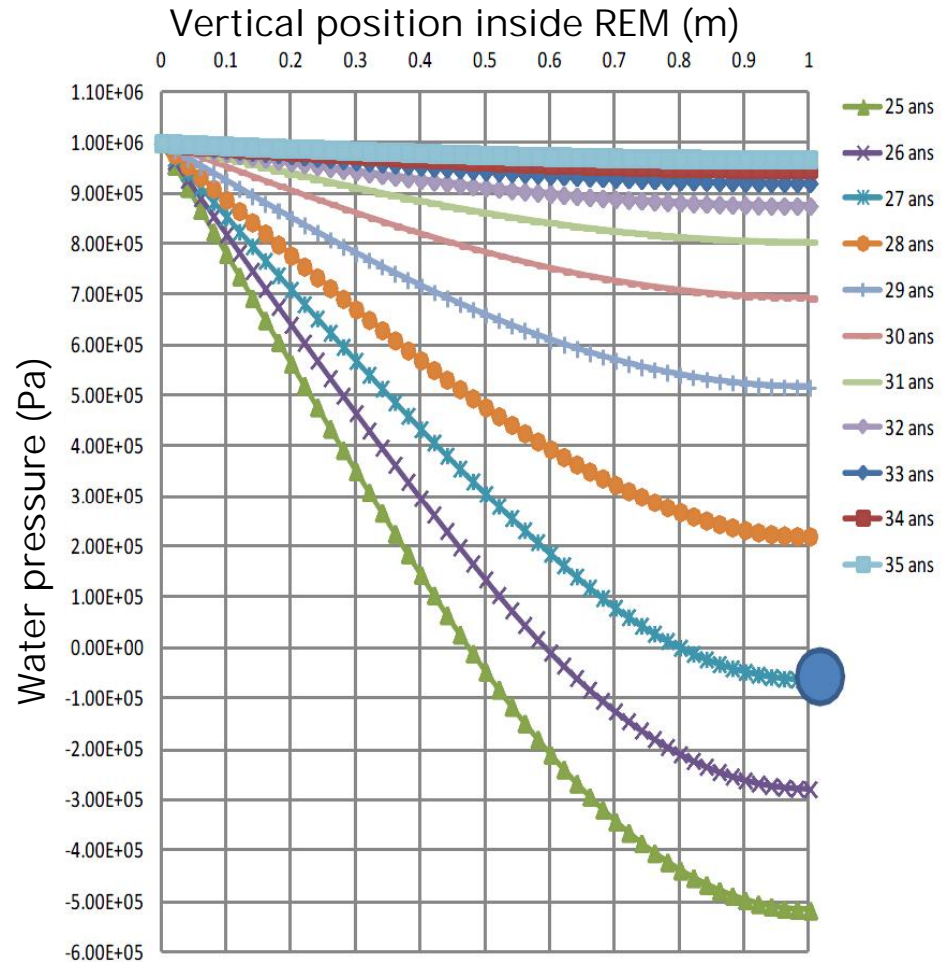


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# REM : ongoing work and first results

## REM first hydraulic (no mechanic) numerical simulation

Expected resaturation time :  
25-30 years

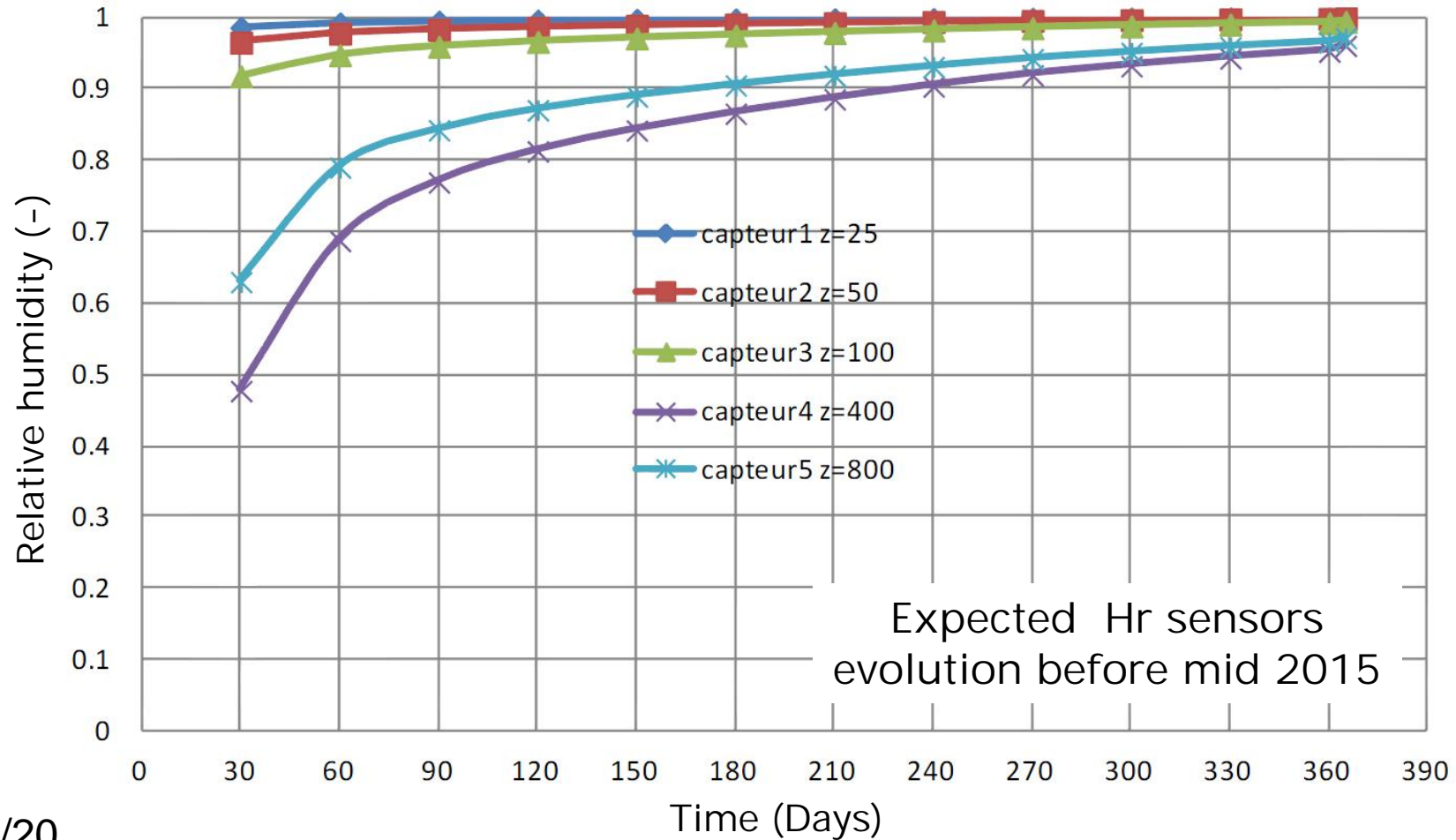


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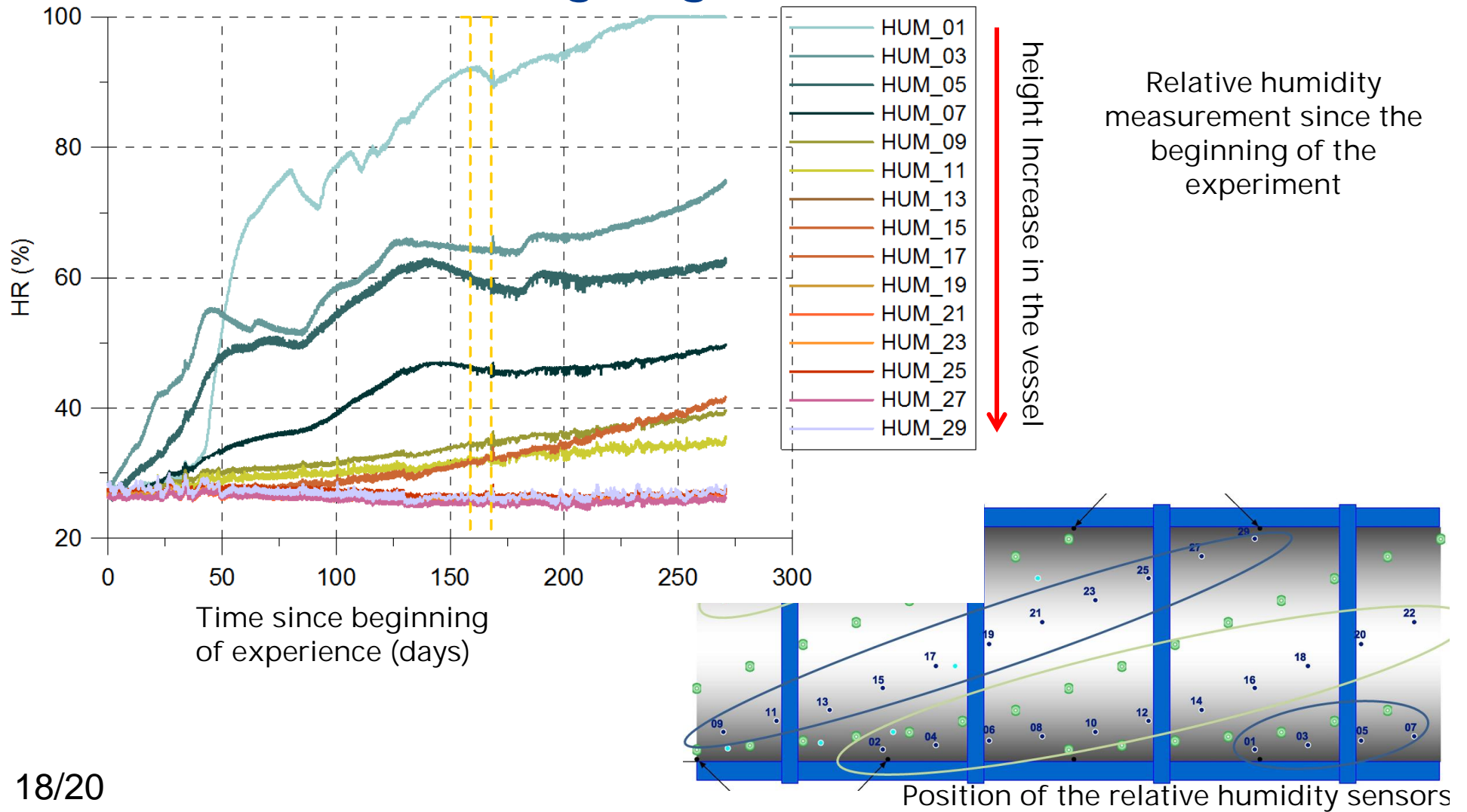
# REM : ongoing work and first results

## REM first hydraulic (no mechanic) numerical simulation



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# REM : ongoing work and first results



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# REM : general achievement (within DOPAS)

## Experimental results (REM + satellite experiment)

- » Evolution of the resaturation in time during 1.5 years
  - Expected resaturation of around several centimeters
  - Evolution of the relative humidity over the whole volume of the cell
- » Evolution of the swelling pressure during 1.5 years over the whole volume of the cell
- » *The experiment will be maintained at least for 10 years to see the evolution of resaturation and to help develop a specific rheological model*

## Numerical simulations

- » Simulation of the resaturation period
  - Evolution of the saturation (relative humidity) over the whole cell
  - Evolution of the swelling pressure over the whole cell
- » *Development of a specific rheological behavior*
- » *First benchmark*
  - *To compare simulations predictions and experimental results*
  - *To compare results of different simulations / codes*

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# Thank you

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