UNIVERSITY OF SURREY

ERICA
ENGINEERED CALCIUM SILICATE HYDRATES FOR APPLICATION

ESR 9:
Upscaling towards applications - water transport in C-S-H agglomerates studied by MRI measurements

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OBJECTIVES

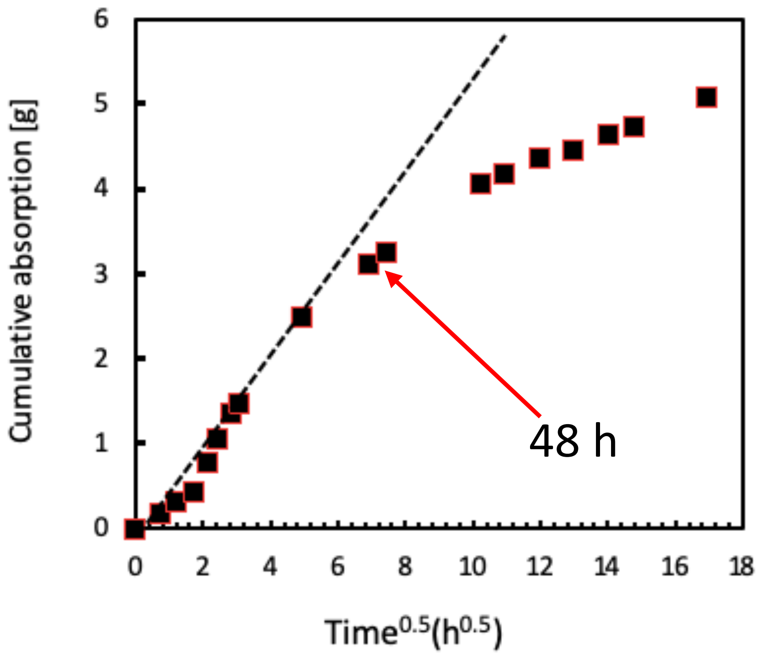
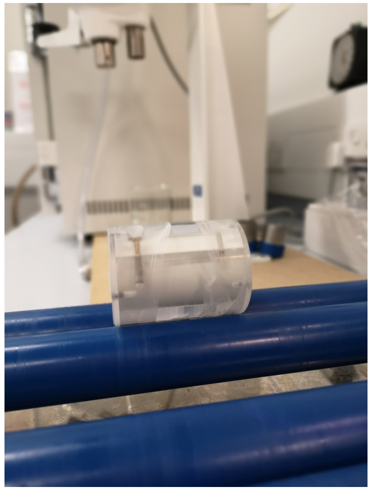


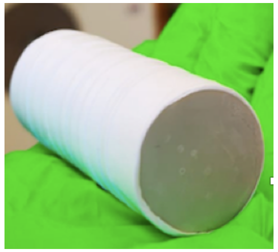
Figure 1: *Water uptake of oven dried sample in 40^{o}C over square root of time*.

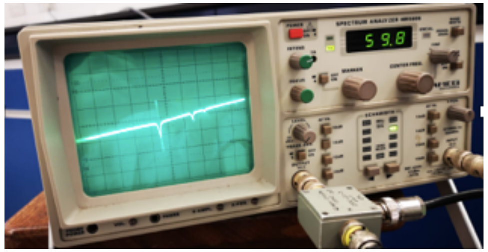
To determine at macro-scale if the dynamic microstructure of cement paste can explain anomalous water transport (MRI studies).

SET UP



Material	Shape	Water to cement ratio	Sample size [mm]
White cement	Cylinder	0.4	Diameter : 25 Length: 60





IMAGING TECHNIQUE

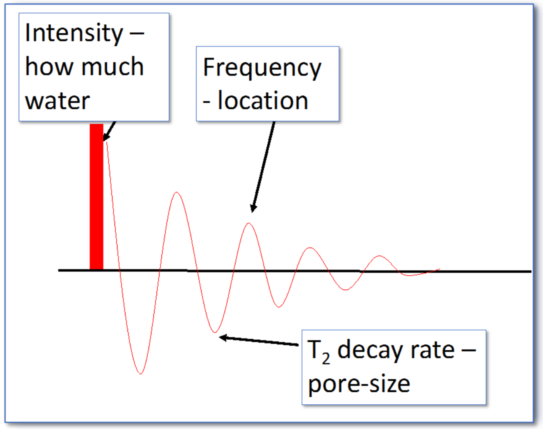


Figure 2: *Excitation pulse and signal decay.*

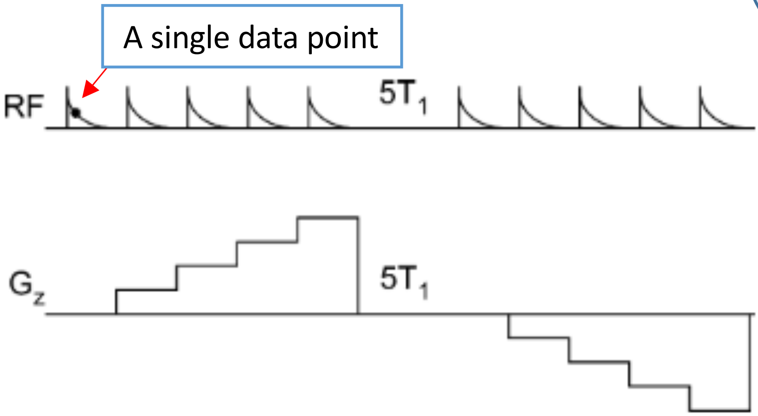


Figure 3: *SPRITE pulse sequence,* K. Deka *et al,* 2006

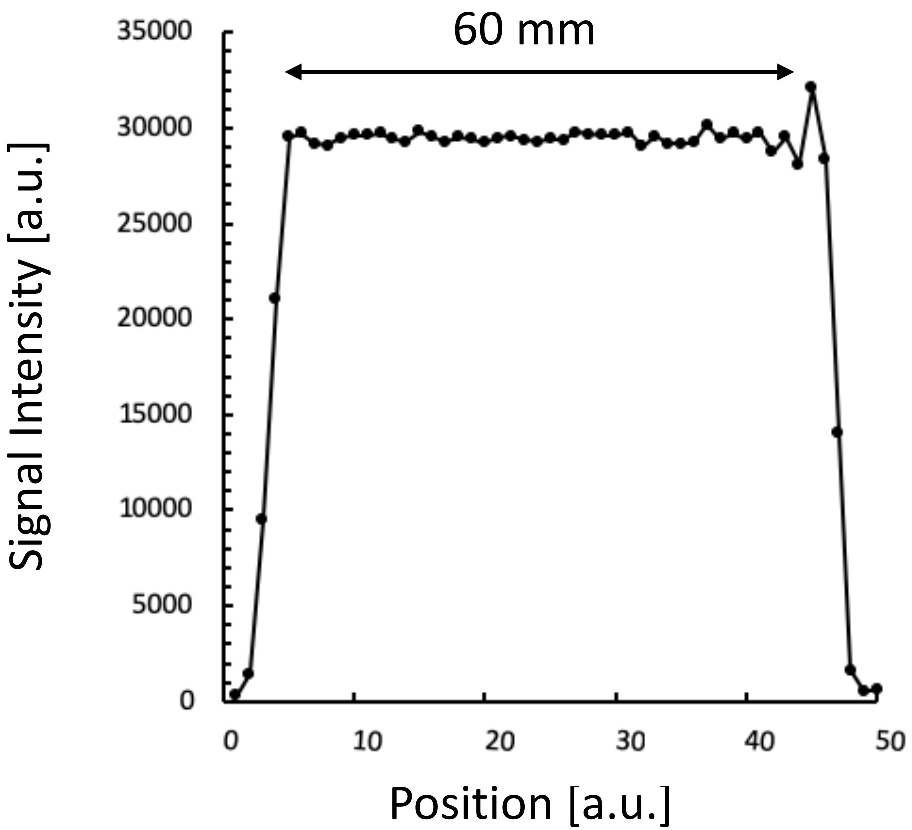
Advantages of Single-Point Ramped Imaging with T_1 Enhancement (SPRITE) technique:

- enables imaging of very short T_2 water in small pores as found in cement;
- enables additional T_1 contrast;
- minimizes image artifacts due to gradient vibration & fast switching;
- tolerant of extremely inhomogeneous magnetic fields;
- modest imaging times;
- the resolution is limited only by the maximum gradient available.

$$S = \rho_o e^{-\frac{t_p}{T_2^*}} \left(\frac{1 - e^{\frac{-TR}{T_1}}}{1 - \cos\alpha \, e^{\frac{-TR}{T_1}}} \right) \sin\alpha$$

Spin density → water content

1D PROFILE



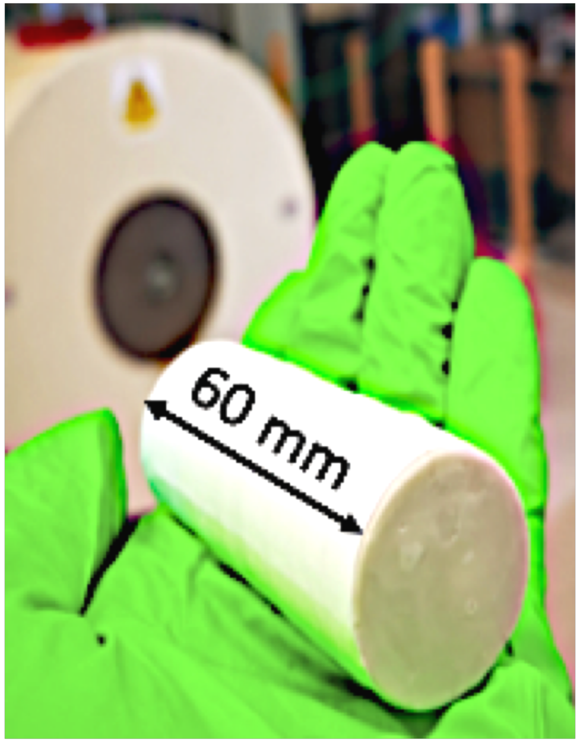
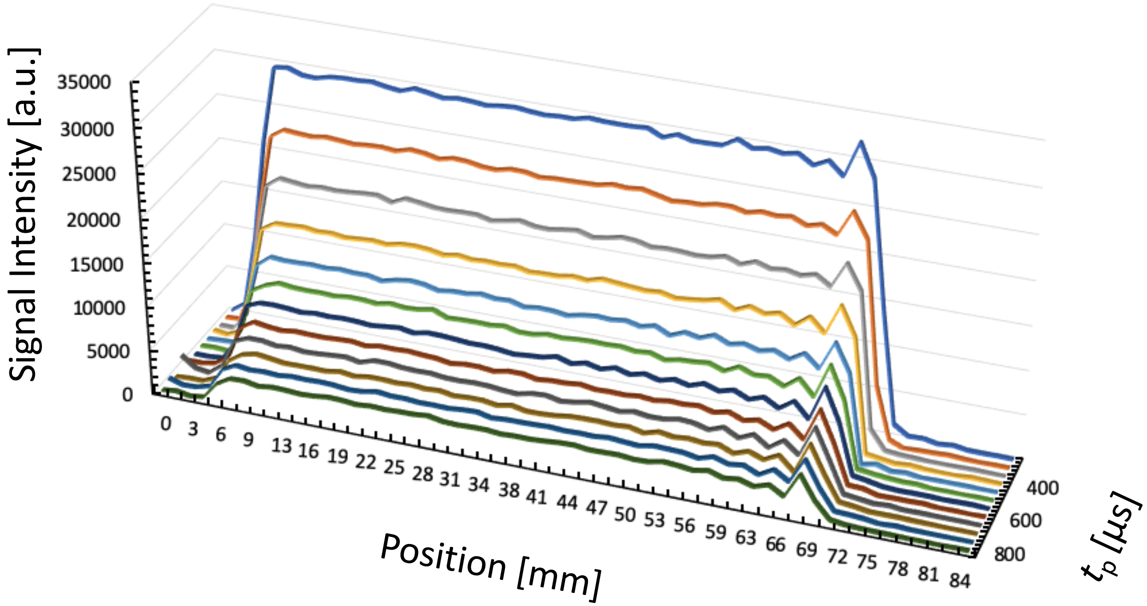


Figure 4 : *T^*_2 weighted 1D SPRITE image of the uniformly cured/wet sample before exposure to drying, $t_{p=}$100 µs. The signal intensity, S, from any point on the image is related to local proton density, ρ.*

Right: A 60 mm long sample with w/c=0.4 , sealed from the outside by sealant and PTFE tape.

FITTING 1D PROFILES



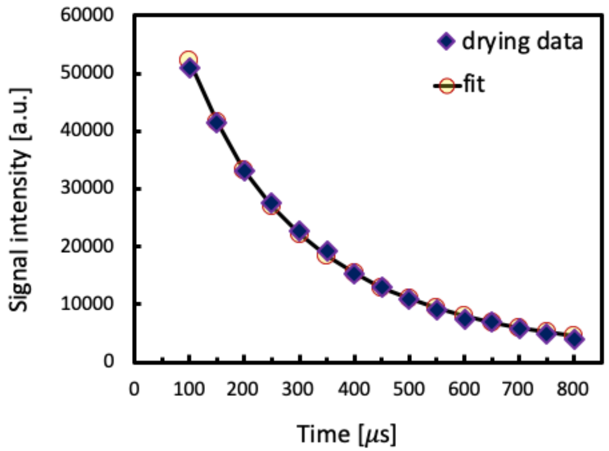


Figure 6: Fitting to the exponential decay to extract T_2 components.

Figure 5 : T^*_2 weighted 1D SPRITE images of the 28-days cured cement paste sample. Twelve profiles are plotted in 50 µs intervals in t_p, starting from 100 µs. These images represent the moisture present in the cement paste sample (w/c=0.4).

$$S = \sum_{i=1:n}^{n} \rho\left(T_1^i\right) \cdot e^{\left(\frac{t_p}{T_2^*}\right)} \left[\frac{1-e^{\left(-\frac{\tau}{T_1}\right)}}{1-\cos\alpha \cdot e^{\left(-\frac{\tau}{T_1}\right)}}\right] \sin\alpha \, dt$$

where,

T_1,T_2^*- the longitudinal and transverse relaxation times [µs],

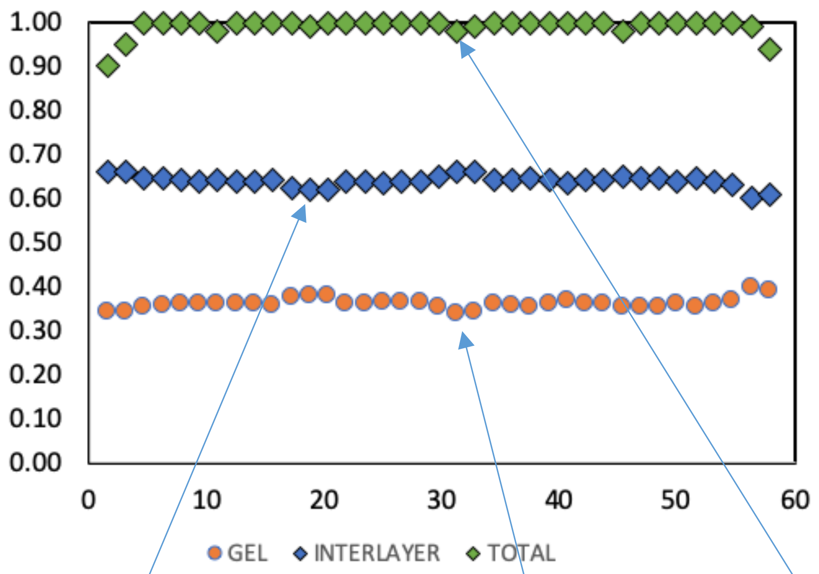
τ– the pulse-pulse interval time [µs],

t_p – the encoding time [µs],

α – the flip angle [radians].

1st DRYING CYCLE

Before drying



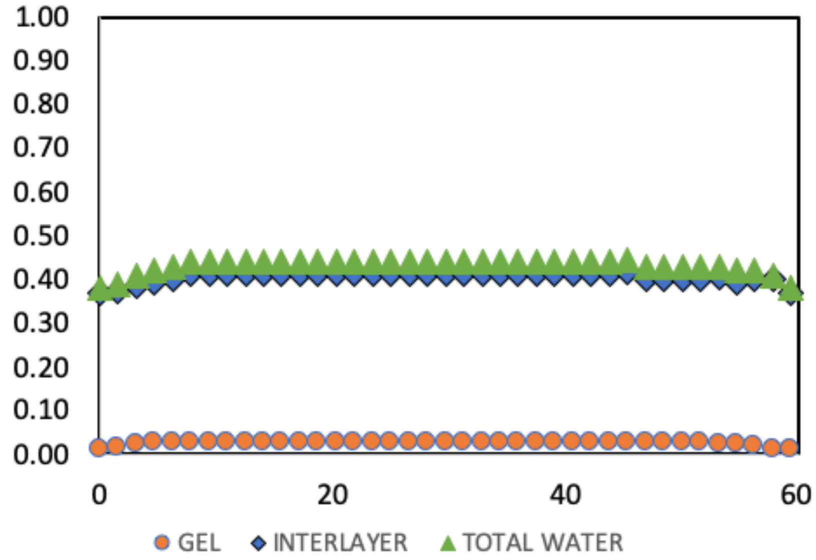
Position [mm]

Interlayer pores

Gel pores

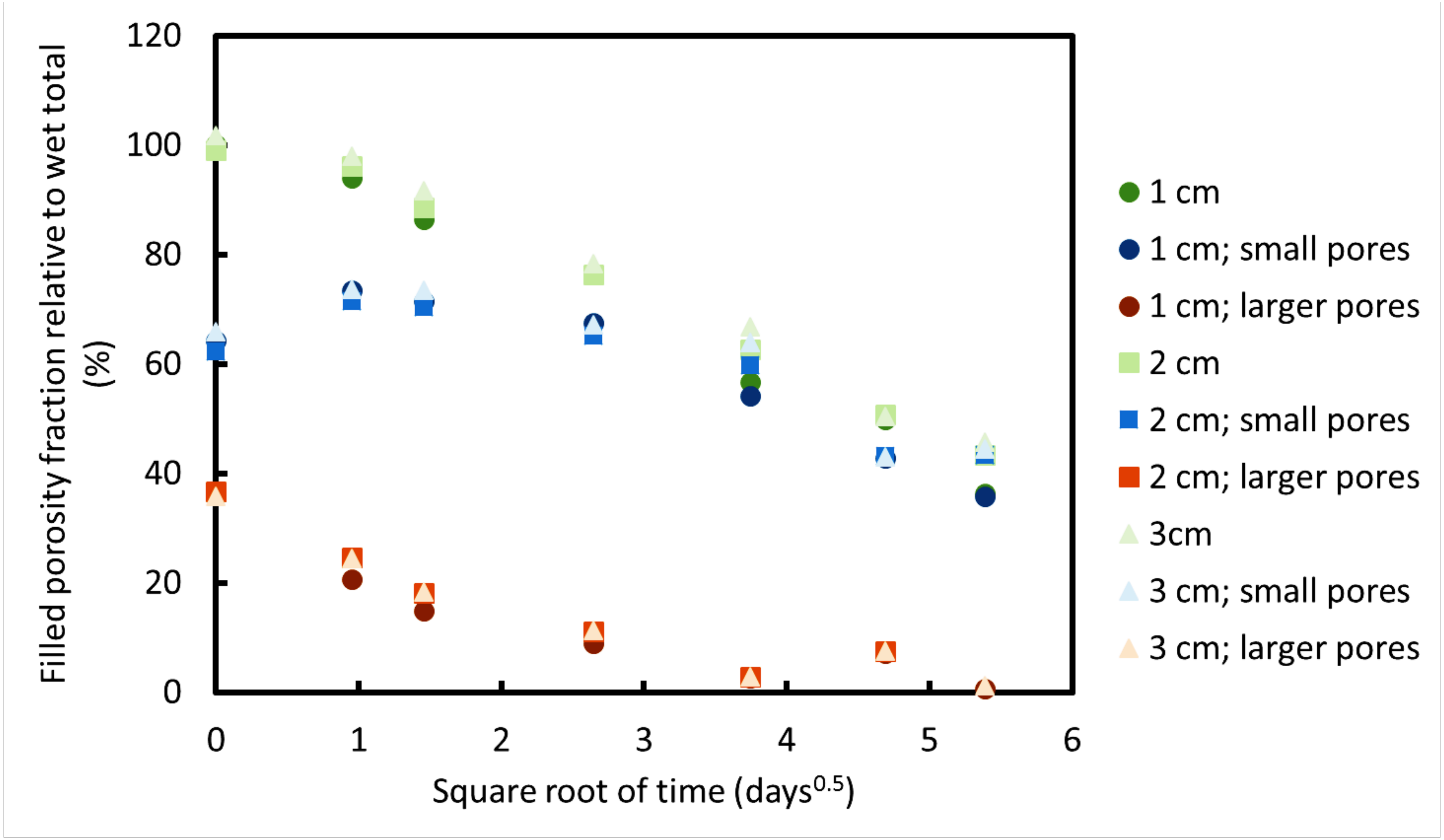
Total

After drying

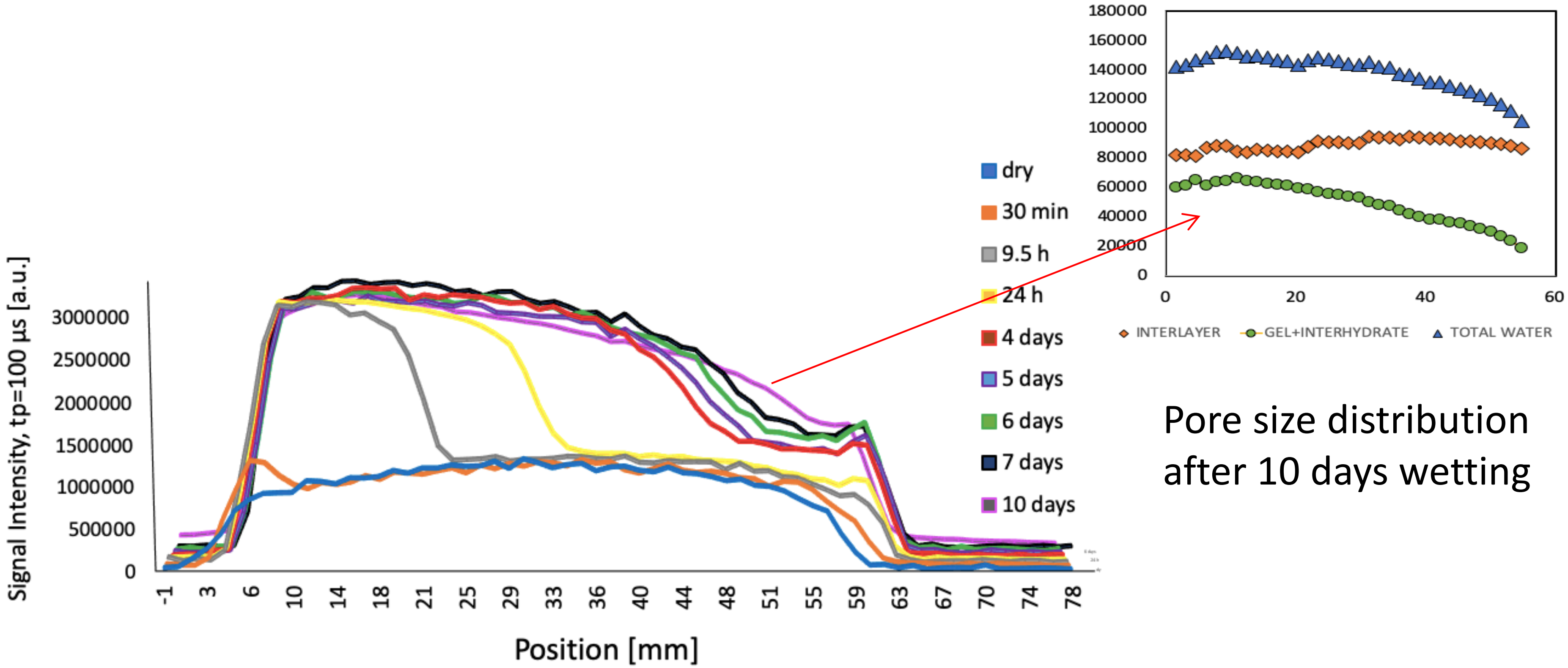


Position [mm]

1st DRYING CYCLE



1st WETTING CYCLE



Pore size distribution after 10 days wetting

Figure 9. *Water ingress profiles. Water enters from left.*

CONCLUSIONS

- In this experiment, we observe that capillary and gel pores (T_2 = 400 μs) are initially emptied. Smaller interlayer spaces first increase (150 μs) because larger pores collapse and because a residual surface layer of water is left behind in gel pores. In this sample, the drying is uniform with position, especially given the signal loss decreases close to $t^{0.5}$.
- During 1st wetting cycle at about 4 days we observe a slowing down in water absorption (at 44 mm).
- Future experiments will compare different drying regimes and the first and second drying cycle. Results will be compared with a new transport model solved using a Monte Carlo simulation code.

PLANNED SECONDMENTS

- LAFARGEHOLCIM (LYON, FRANCE)

Main question: How pore size distribution (PSD) changes depends on different moisture content in carbonated samples and non-carbonated (1st and 2nd sorption cycle)?

- 1st visit (April 2019): sample preparation
- 2nd visit (October 2019): sample cutting and pre-carbonation conditioning
- 3rd visit (November 2019): to start of carbonation
- 4rd visit (December 2019): to start of pre-test conditioning
- 5th visit (January-February 2020): to test capillary rise, gas diffusivity and vapor permeability

(Additionally at Surrey: MRI, NMR and GARfieldNMR)