SIP responses of building materials, investigation of correlations with specific surface and dominant pore throat size

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Many damage processes in building stones are driven by moisture ingress and subsequent decay due to solving, blistering or different types of corrosion. Hence, measuring moisture and/or any material property that is connected to the absorption/desorption behaviour of a porous medium is helpful for building engineers concerned with conservation or restoration. Since the SIP method is sensitive to both the amount and chemistry of a pore fluid and pore space properties its applicability and practical use as a non-destructive testing tool for moisture damages is studied at BAM.

Scott and Barker (2003) demonstrated for sandstones a good correlation between the frequency of the SIP phase peak and the dominant pore throat size measured in mercury-intrusion experiments. Their observations basically go back to the relaxation model developed by Schwartz (1962) and Schurr (1964) for spherical particles in ion solutions. In their model the particle diameter R of glass beads and the relaxation time τ of the ions in the solution were linked according to:

$$\tau = R^2 / D_S \quad \text{and} \quad D_S = \mu_S kT$$

where D_S is the effective diffusion coefficient, μ_S is the effective ionic mobility, k is the Boltzmann's constant and T is the absolute temperature and. Scott and Barker argued that in the case of consolidated materials like sandstones the "critical length scale" leading to the relaxation process are not grain sizes, but pore throat sizes.

In order to further explore this relationship for building materials (with a particular focus on sandstones) a new study has been carried out covering with the samples a wide range of textural characteristics. The involved materials comprised sandstones, tuffs, bricks, artificial sand-limestones, asphalt and concrete. The pore-throat size distributions of all samples have been measured in mercury-intrusion experiments and the specific surfaces determined in BET analyses. Most materials had unimodal pore throat size distributions and a dominant pore throat size could be defined. Figure 1 shows the dominant pore throat size versus the position of the phase peak (frequency_peak) and the corresponding peak relaxation time (tau_peak), respectively for the new set of data and literature values.

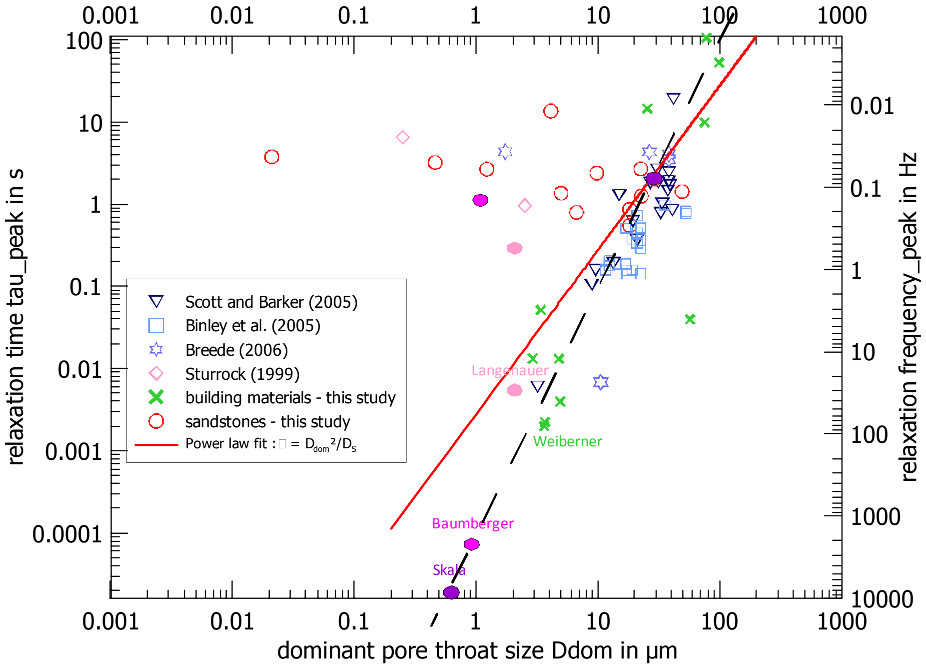

Fig. 1: Dominant pore throat sizes (Ddom) versus peak relaxation time (tau_peak) for sandstones and building materials saturated with brines of ≈ 0.1 S m^{-1} fluid conductivity

Interesting are the following observations:

1) Some of the samples follow the predicted trend (Scott and Barker 2003) of decreasing relaxation time with decreasing dominant pore throat size. Most all of them are building materials like aerated concretes, bricks and tuffs.
2) Almost all sandstones of this study with dominant pore throats below 5-10 µm show relaxation times between 1 and 10 s and do not follow the predicted trend.
3) Some of the samples, which had unimodal pore throat size distributions in the mercury-intrusion experiments showed SIP phase curves with two peaks (e.g Baumberger and Langenauer sandstone, displayed in Fig. 2) and were hence marked with two dots in Fig. 1.
4) Other samples, which had a bimodal pore-size distribution in the mercury intrusion also shows a bimodal SIP phase curve (like Skala sandstone in Fig. 2), these are also marked with two dots in Fig. 2.
5) Between 1-10 µm we observe something like a “transition zone” where it is unclear what exactly controls the relaxation behaviour.

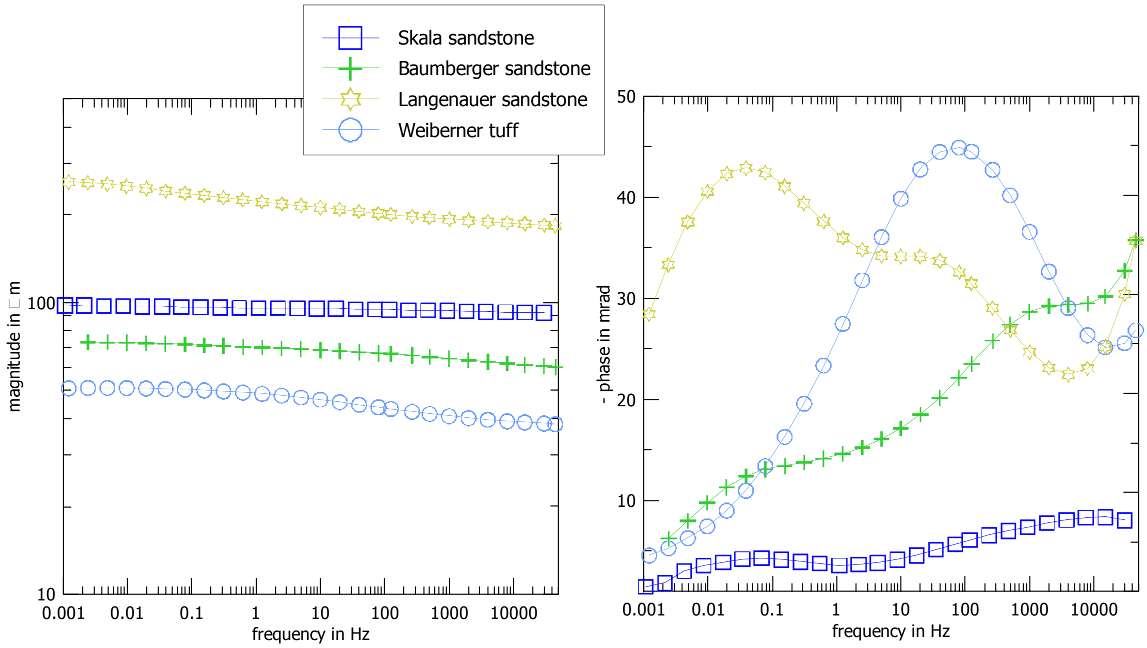

Fig. 2: SIP magnitude (left) and phase (right) spectra of three sandstones and one tuff, all samples are saturated with 0.01 M NaCl ($\sigma_{fl} \approx 0.1$ S m^{-1}).

The specific surfaces of the samples not following the predicted trend are usually high and the porosities low (compare with Kruschwitz et al. 2010). Currently the mineral composition and other geometric features of the pore structure are investigated in thin sections and by mineral analysis. A possible explanation for the observed phenomena might that different relaxation processes are competing. The low-frequency relaxation process might be due to surface roughness or a certain mineral or chemical compound causing slower diffusion.

References

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