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Monitoring free swelling of MX80 bentonite in a narrow channel using X-ray imaging

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ABSTRACT

Axial wetting and free swelling of compacted MX-80 bentonite samples in an aluminium tube of diameter 10 mm were studied using X-ray imaging (Fig. 1). The experimental setup is reminiscent of bentonite swelling into a fracture of rock surrounding the bentonite buffer in a planned nuclear waste repository. The method is based on comparison of X-ray images of the sample in the original unwetted state and in the wetted and deformed state. The method is similar to that introduced recently for full 3D reconstructions [1]. The measurement yields the time evolution of the axial distribution of the partial densities of the bentonite and water during the wetting process. To this end, the X-ray beam hardening and irregularities in the beam intensity were dynamically corrected (Fig. 2) in order to obey the linear relationship between the X-ray attenuation coefficient and the partial densities of bentonite and water (Fig. 3). The deformation of the samples was measured by tracking the metallic particles added in the bentonite powder (Fig. 4). The local dry density at each instant of time was obtained based on the initial dry density and the measured displacement field. The local water content in the sample was then found based on the calibrated correlation shown in Fig. 3. A typical duration of measurements with a sample of length 20 mm was four days. Three initial water contents (w_0) of the bentonite samples used were 12%, 17% and 24% while the initial dry density was fixed to 1.65 g/cm^3. The salinity of the water used in wetting was 0.1 M (NaCl). Figure 5 shows the final result for a bentonite sample (w_0 = 12%) at four different time steps.

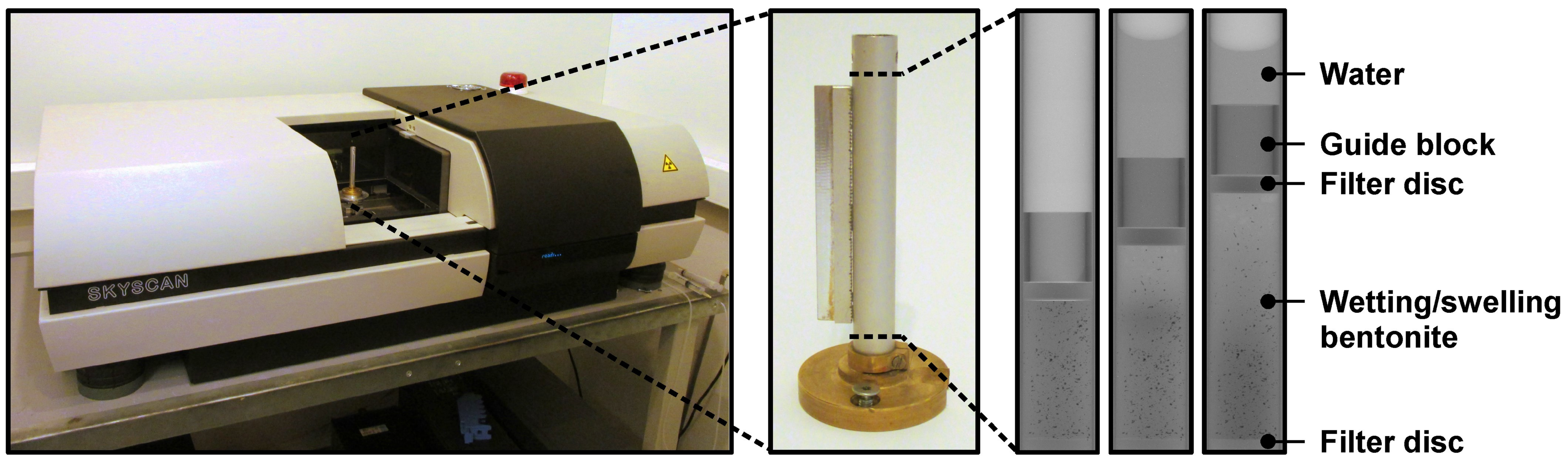

Figure 1: Skyscan 1172 microtomographic device used in X-ray imaging, an aluminium tube sample holder and X-ray images (I/I_0=exp($-\mu x$)) of the tube during swelling.

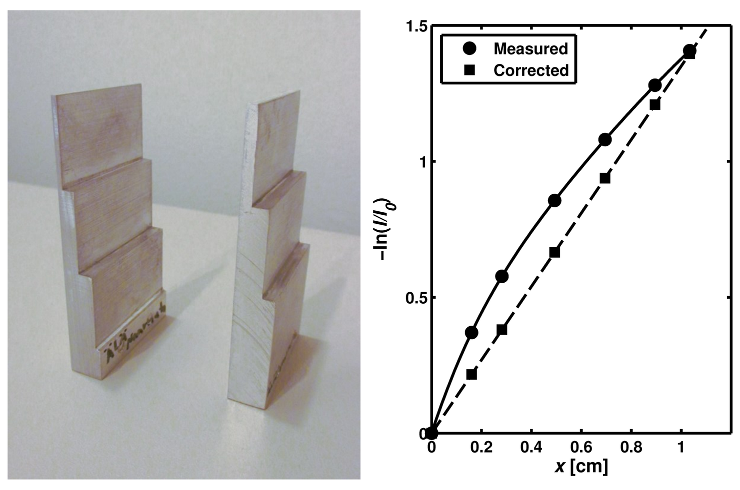

Figure 2: The dynamic flat field correction is used to alleviate artifacts arising from irregularities of beam intensity and from beam hardening effect. The correction is based on taking X-ray images of aluminium plates of varying thickness.

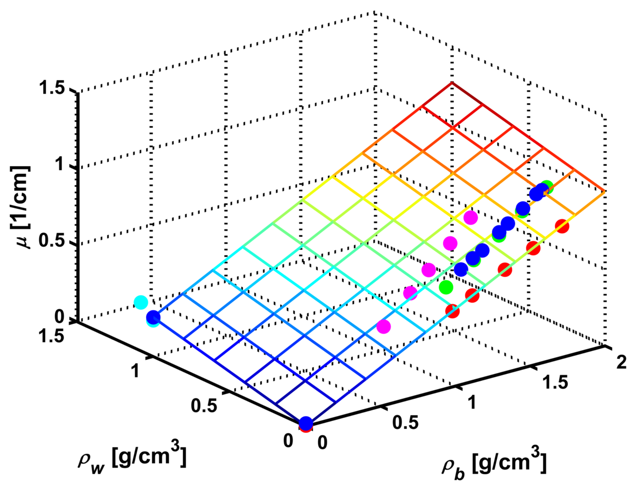

Figure 3: The measured X-ray attenuation coefficient (μ) of calibration samples (solid symbols) together with the linear fit (the plane $\mu=\mu_0+c_b\cdot\rho_b+c_w\cdot\rho_w$).

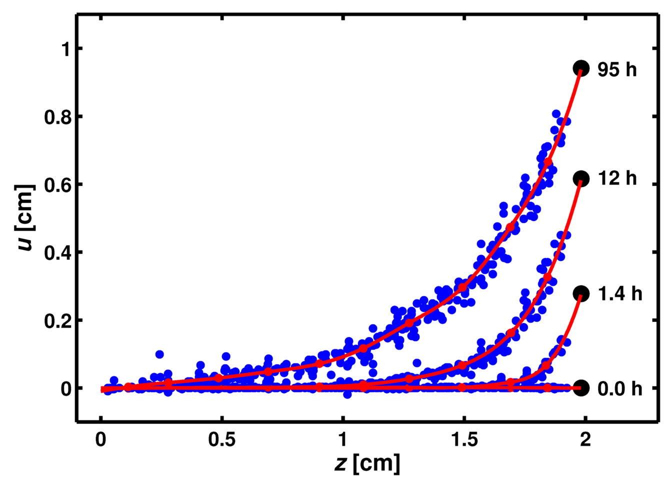

Figure 4: The axial displacement (u) of swelling bentonite at various times obtained by tracking added tracer particles visible in the X-ray images (see Fig. 1).

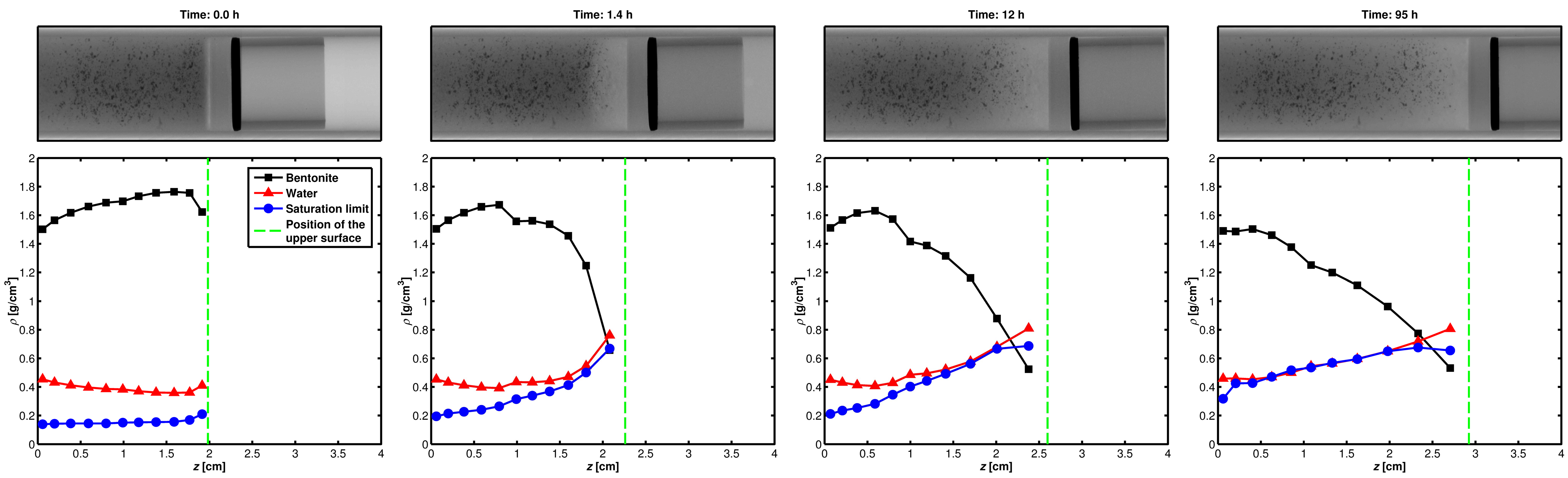

Figure 5: The measured axial distribution of dry density and water content in a freely swelling bentonite sample (w_0 = 12%) at four different times. Also shown are the corresponding X-ray images of the sample (horizontally above the graphs).

CONCLUSIONS

A non-destructive method based on X-ray imaging has been developed and used to study free swelling of MX-80 bentonite in a narrow channel. The results obtained seem qualitatively plausible. The accuracy of the method depends considerably on the X-ray beam stability and the success of the deformation measurement. The results are useful e.g. in validating models of bentonite swelling and eroding in rock fractures as well as of bentonite buffer behaviour, in general.

ACKNOWLEDGEMENTS

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REFERENCES

[1] T. Harjupatana, J. Alaraudanjoki and M. Kataja, "X-ray tomographic method for measuring three-dimensional deformation and water content distribution in swelling clays", *Appl. Clay Sci.* 114, 386-394 (2015).

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