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Closure to the discussion of "ANALYSIS OF THE WATER ABSORPTION TEST TO ASSESS THE INTRINSIC PERMEABILITY OF EARTHEN MATERIALS"

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## **1/ Introduction**

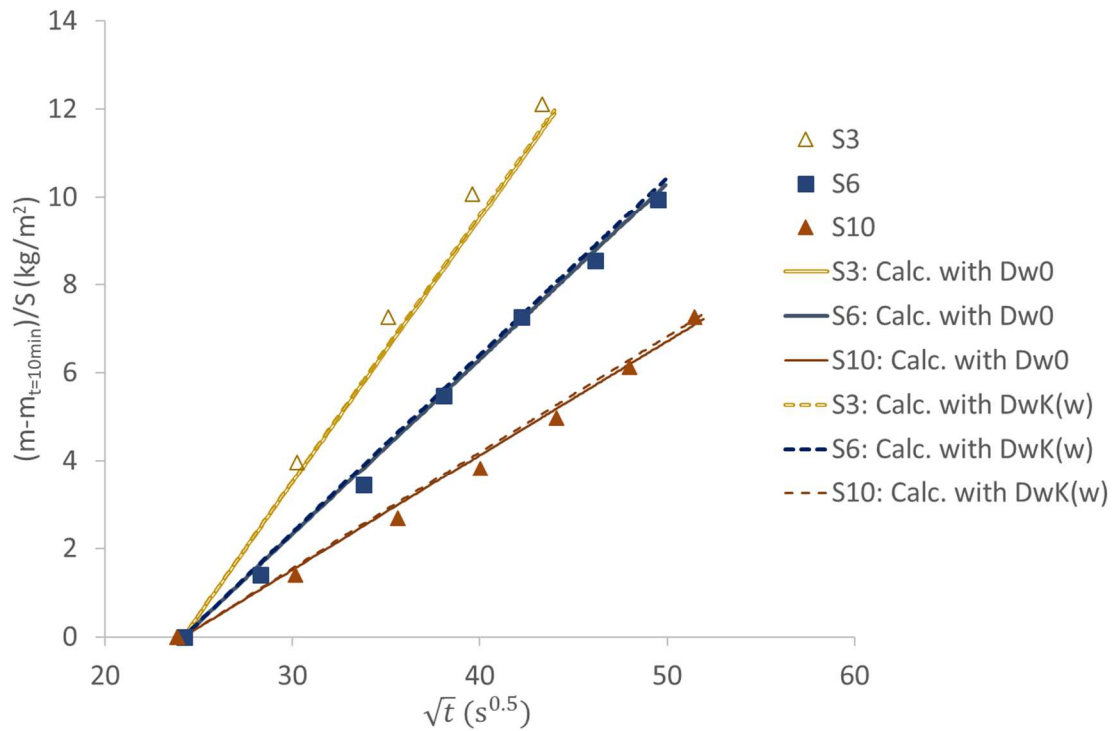
The main result of the paper [1] was the indirect estimation of the intrinsic permeability of the material using a water absorption test. The discussion focused on a secondary observation of the paper, which is the comparison between the results obtained with the analytical solution developed in [1] and the Kunzel/Keiss approach. The authors of [1] want to thank H. Janssen for the interesting scientific exchanges that were initiated.

In particular, the two major criticisms, which are summarized in the highlights of the discussion, are an error in the simulation of the water absorption experiment using the exponential expression for the diffusion coefficient  $D_w^K(w)$ , and the fact that a water uptake experiment should not be modelled using a constant water diffusion coefficient.

## **2/ Simulations with $D_w^K(w)$**

Concerning the first point, we agree with the discussion. There was an error in the expression of the coefficient  $D_w^K(w)$  as it was implemented in Comsol: it was inadvertently multiplied by a factor  $\pi$ . Making this correction leads to the results reported in Figure 1.

The authors of [1] sincerely apologize for the error, that would have been corrected in an erratum of the paper. Nonetheless, the comparison between  $D_w^K(w)$  and  $D_{w0}$  is not the key result of the paper, and the fact that the use of  $D_w^K(w)$  can reproduce the evolution of the mass increase during the absorption test is actually quite normal, as well as it is the case for the use of  $D_{w0}$ , for the reasons explained in the discussion. The objective of the simulations presented in Figure 1 was to analyze whether the semi-infinite medium assumption, which was used to estimate the value of  $D_{w0}$  through the analytical solution, remains acceptable for a sufficient time period.



**Figure 1.** Correction of Figure 9 in [1]: Simulation of the water absorption test considering either  $D_w = D_{w0}$  (plain lines) or  $D_w = D_w^K(w)$  (dotted lines) for the samples S3, S6 and S10 and comparison with experimental data (dots).

### 3/ Discussion on the variation of $D_w$ with water content

Concerning the second point, the authors of [1] want to underline that they are aware of the importance of taking into account the variation of mass transport coefficients with saturation ratio as evidenced by many of their previous publications (for example [2-4]). The objective of the paper was not to study the evolution of the water diffusion coefficient with water content, but to study the possibility of having a simplified approach in order to analyze water absorption tests of compacted earth materials. There is no attempt to generalize the results to other porous materials like concrete or limestone nor to other applications than the one presented. In our view, the results of [1] are not in contradiction with published studies of the past decades, but show a particular case for which the use of a constant value of the water diffusion coefficient can provide an interesting result. For example, this approach would certainly not allow an accurate estimation the water penetration height, but this is not its purpose.

We agree that taking into account a proper variation of the water diffusion coefficient with water content should lead to improved results. However, this relationship is not established for earthen materials. Indeed, many relationships exists to evaluate the variation of  $D_w$  with water content (for example, [5-8]). Even limiting oneself to the relationship presented in [8], which is cited in the discussion, the  $D_w(w)$  function is not unique, and at least one shape parameter, denoted by  $n$ , must be fitted. The appropriateness of using  $n = 6.91$ , which is an implicit assumption of Kunzel's law is not proven for earthen material. In particular, the lack of correlation between the measured intrinsic permeability (that is  $\kappa_0 = \kappa(w = w_f)$ ) and

$D_w^K(w = w_f)$  reported in Figure 2, suggests that additional works are needed in order to use this kind of exponential relationship to estimate correctly the intrinsic permeability. The use of the simplified approach developed in [1] led to acceptable results.

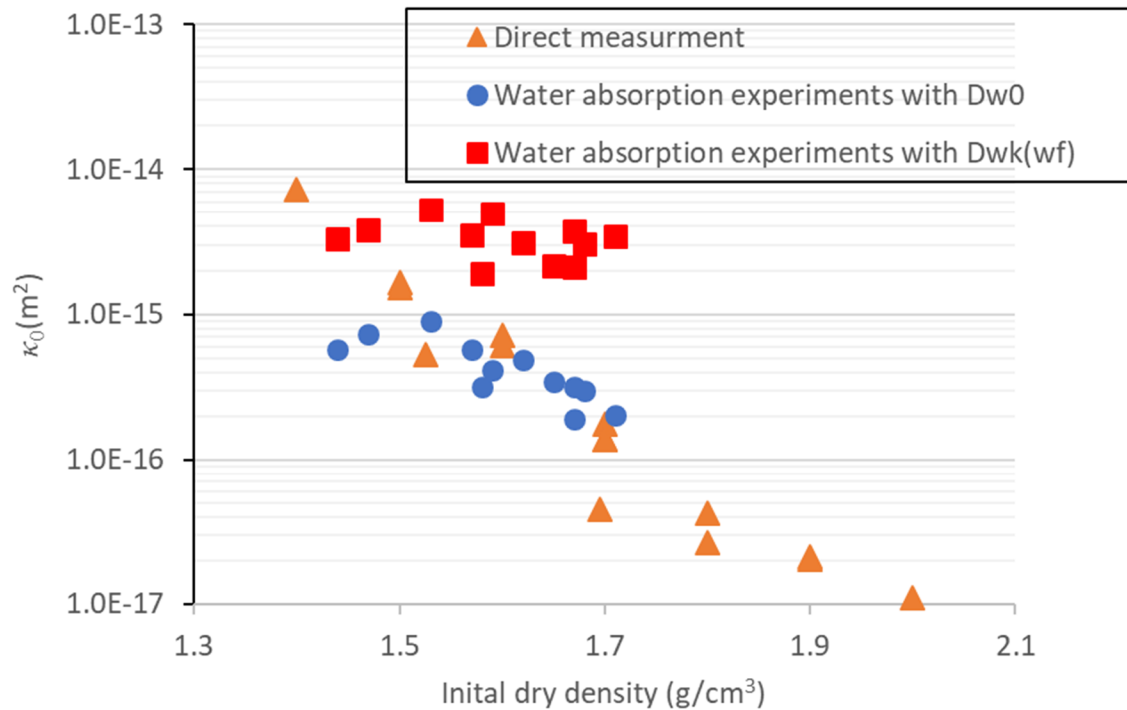


Figure 2: Comparison of intrinsic permeability values estimated from water absorption tests considering  $D_w = D_{w0}$  (circles),  $D_w = D_w^K(w_f)$  (red squares) or permeability tests (orange triangles).

Most available models and approaches are based on assumptions. For example, the mechanical behavior of a soil is neither isotropic nor elastic. But is it correct to suggest that performing poroelastic simulations of soils denies all the research undergone in the field of geotechnics? Obviously not if the use of such a simplified approach is justified in the context of the study. In particular, analytical solutions, like that presented in [1], are primarily of interest for engineering purposes. Typically, their development requires simplifications and a linearization of the problem ([6] for example). In the same spirit, most hygrothermal models assume a local thermodynamic equilibrium, isotropic properties, constant vapor diffusion coefficient and, notably, neglect the effect of gas compressibility and viscous dissipations in the heat balance as well as the impact of the variation of vapor mass within the pores in the overall mass variation of water. These assumptions are incorrect from a theoretical standpoint, but they are practically acceptable since they do not significantly affect the results in the context of their field of application. It is the same for the assumption that  $D_w = D_{w0}$ : it is theoretically incorrect but, given the results that are obtained (Figure 2), it appears to be acceptable for the purpose of this study.

#### 4/ Conclusion

In the paper [1], the objective was to propose a simplified approach, which can provide, in our opinion, interesting results. We acknowledge the author of the discussion to have identified one error in the simulation with the coefficient  $D_w^K(w)$ ; we have corrected this error here.

Nevertheless, this error concerns a secondary result of the study, and does not affect the key result of the paper which is the comparison between the measured and indirectly estimated intrinsic permeabilities through the development of an analytical approach.

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