Reply to Janssen, H. Comment on “Cabrera et al. A User-Friendly Tool to Characterize the Moisture Transfer in Porous Building Materials: FLoW1D. Appl. Sci. 2020, 10, 5090”

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1. Introduction

A significant part of the critical comments by Prof. Janssen, in relation to the work presented in [1], are based on an assessment of statements that are not really made in the latter work. As it is scientifically inconsistent to discuss issues that one has not stated, the present reply is based on analysing the only three issues raised by Prof. Janssen that are very critical to [1]: the scope of the van Genuchten–Mualem model, the capabilities of FLoW1D, and the validity of the parameter estimations presented in [1].

2. Discussion

2.1. The Van Genuchten–Mualem Model

First, Prof. Janssen claims that [1] is invalid because the hygric properties of porous building materials cannot be described by unimodal van Genuchten–Mualem equations. While the authors of the present reply do not feel able to reduce the scope of the van Genuchten–Mualem equations as drastically as [1] does, it is agreed that the model has limitations. Consequently, nowhere in [1] is it stated that the van Genuchten–Mualem equations constitute the conceptual framework containing the complete universal behaviour of porous building materials. They are simply a tool included in the formulation presented in [1]. Believing that these equations are a panacea for any conceptual characterisation is contrary to the work presented in [1], which focuses on providing a simple tool (FloW1D) that can be easily adapted to improve the interpretation of water absorption by capillarity (WAC) tests. Additionally, a strategy of simplicity is adopted, as repeatedly stated in [1]: “(allow) the users to modify the code according to their needs” modifying, for example, the implemented functions. The adaptivity of FloW1D and its ultimate cause, is contrary to the dogmatism imputed to us.

2.2. The FLoW1D Model

Secondly, the low computational efficiency of FLoW1D is raised by Prof. Janssen. This is true, and it is to be expected. The computational simplicity, and the use of a spreadsheet as the interface for implementation, comes at a cost in numerical terms. That is why the only scope explicitly given to FloW1D in the conclusions of [1] is the analysis of WAC tests. In no case does it pretend to be a general simulation tool. However, FloW1D does allow for the confident simulation of WAC tests. The tremendous simplicity of FloW1D is the source of its robustness (only for this question, the expression “robustness” is applied in [1] to qualify its ability to solve simulations of WAC tests). Logically, in an explicit method, the robustness is conditioned by the size of the spatial grid and the maximum time step selected. Thus, the case identified as “variant 1” by Prof. Janssen, as an example of the
malfunctioning of FloW1D, Prof. Janssen changes from solution 1 presented to solutions 2 and 3 when 400 and 800 nodes are used, respectively, instead of 100 nodes (Figure 1). Users, as stated in Section 3.2 of [1], should adjust the grid size according to their problem. The robustness is evidenced by the fact that, even Prof. Janssen used the poor grid, FloW1D was able to provide a solution.

Figure 1. (Left panel) Evolution of the cumulative water mass in for: (a) 100 nodes, (b) 400 nodes and (c) 800 nodes. Markers, experimental data; solid line, FLoW1D results. (Right panel) Moisture content isochrones (w) obtained with FLoW1D for: (d) 100 nodes, (e) 400 nodes and (f) 800 nodes. Times: 10 s for the first minute and 20 s for the next four minutes. Using the parameters of OPS limestone, variant 1 is given in Table 1 from the critical comments by Prof. Janssen.

Moreover, the scientific community is familiar with the Excel® spreadsheet, and it is aware of the scope and limitations of its Solver Add-in for dealing with parameter estimation problems. Because of this, in the final sentence of [1], it is stated quite clearly that Excel® + FLoW1D should be used for environments such as those presented in our work. The aim of [1] is not to take a fundamental step in the “total” characterisation of building materials. It is only intended to facilitate the work in laboratories by helping to improve the interpretation of WAC tests.

2.3. Parameter Estimation

Finally, the quality of the parameter estimation made in [1] is questioned by Prof. Janssen. Potential users of FLoW1D work in laboratories are already used to testing porous
Finally, the quality of the parameter estimation made in [1] is questioned by prof. Janssen. By fixing \( K \) to the values of \( 1.27 \times 10^{-13} \) and \( 8.38 \times 10^{-15} \) m\(^2\) (see Table 3 of [1]) for the ornamental and structural water mass data which, when plotted against the square root of time, fall on a straight line passing through the coordinate origin. This line is univocally defined by a single parameter—its slope. For this reason, if we plot the error surfaces (sum of the squared errors of the model versus the experimental values) when one of the three estimated parameters is fixed and the other two are varied, we obtain the results shown in Figure 2. It can be seen that around the value of the estimated values in our previous work [1] (marked with an asterisk in Figure 2) there are elongated valleys, especially in the intrinsic permeability direction. This indicates a strong correlation between parameters and the ill-posed nature of the problem, as noted by Prof. Janssen. Because of this fact, there are several combinations of parameter values that offer virtually the same level of error.

![Error surfaces for both lithotypes and two-by-two combinations of the parameters](image)

**Figure 2.** Error surfaces for both lithotypes and two-by-two combinations of the parameters (keeping the other one constant).

However, the authors, as shown in [2], carried out a forced infiltration test to determine the intrinsic permeability of the materials and this greatly reduced the uncertainty of parameter identification. Given that the range of variation of the parameter \( K \) was known for the two lithotypes, the initial points for the minimisation algorithm were close to the mean value of \( K \) determined in the infiltration tests. The convergence towards a single minimum is clear and persistent, as can be seen in Figure 3. By fixing \( K \) to the values of \( 1.27 \times 10^{-13} \) and \( 8.38 \times 10^{-15} \) m\(^2\) (see Table 3 of [1]) for the ornamental and structural lithotype, respectively, the same minimum is attained in most cases, and is always very close to the values estimated in [1].
As a consequence of this process, the authors of [1] found that the estimated value of $K$ and the mean value of the experimental results of [2] were similar; therefore, they gave reliability to the estimate made (as explained in detail in [2]).

2.4. Additional Remarks

Finally, some remarks made by Prof. Janssen, can be also discussed. It is necessary to point out that there is a typo in Equation (9) of [1], which, unfortunately, was propagated to Equation (A9). However, as Prof. Janssen was able to verify (readers can also do so, because FLoW1D is freely available in the Supplementary Material of [1]), the typo did not affect FLoW1D, where the water vapour flow was properly implemented. It is also interesting to note that the inconsistency raised by Prof. Janssen after its Equation (6), disappeared when, instead of assuming that a good part of the retention capacity of the material was between $10^{3.5}$ Pa and $10^{6.5}$ Pa of suction, it was considered to be between $10^4$ and $10^6$ Pa. However, claiming that the values in Table 3 of [1], associated with an estimation aiming to stimulate a macroscopical flow, provide parameters that reproduce the topological
structure of the material’s microstructure is perhaps too ambitious. Additionally, the greater representativeness that Prof. Janssen gives to capillary pressure compared to suction is debatable. Additionally, the extent to which the tortuosity values are incorrect could also be analysed, given the vapour transport enhancement mechanisms described and analysed in the literature [3,4].

3. Conclusions

With this reply, the scope of [1] is clarified and the conception of Prof. Janssen is shown. As discussed in [1], it is again shown that FLoW1D is a useful tool for the analysis of WAC tests.

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