Hall's Notes and Queries

NQ1

Water absorption into a short bar

In WT3e[1] (and in earlier editions), Fig 4.2a shows the capillary absorption of water from one end-face of a long (semi-infinite) porous bar. The water content profiles, plotted at 10 min intervals, are computed by Philip's semi-analytical method using a Brutsaert diffusivity function with parameters measured on a fired-clay brick material. Fig 4.2b shows that the profiles scale as $t^{1/2}$.

We could (and probably should) have included a companion figure to show what happens when the bar is shorter (finite), so that the wetting front reaches the far end of the bar and can proceed no further. This case (which represents well the standard sorptivity test on a rectangular bar) is here shown in the new Fig NQ1-1. The same diffusivity function is used as in Fig 4.2, but the profiles are computed numerically using Mathematica NDSolve, with a Neumann zero (no flux) boundary condition at $x = 35$ mm. The profiles are here calculated at 5 min intervals from 10 to 105 min, and are plotted in Fig NQ1-1a, with the semi-infinite case in Fig NQ1-1b for comparison. The cumulative absorption i/f is obtained as the area under these profiles and is shown in Fig NQ1-1c for both the semi-infinite and finite cases.

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[1]C Hall and W D Hoff, Water transport in brick, stone and concrete, third edition, CRC Press, 2021
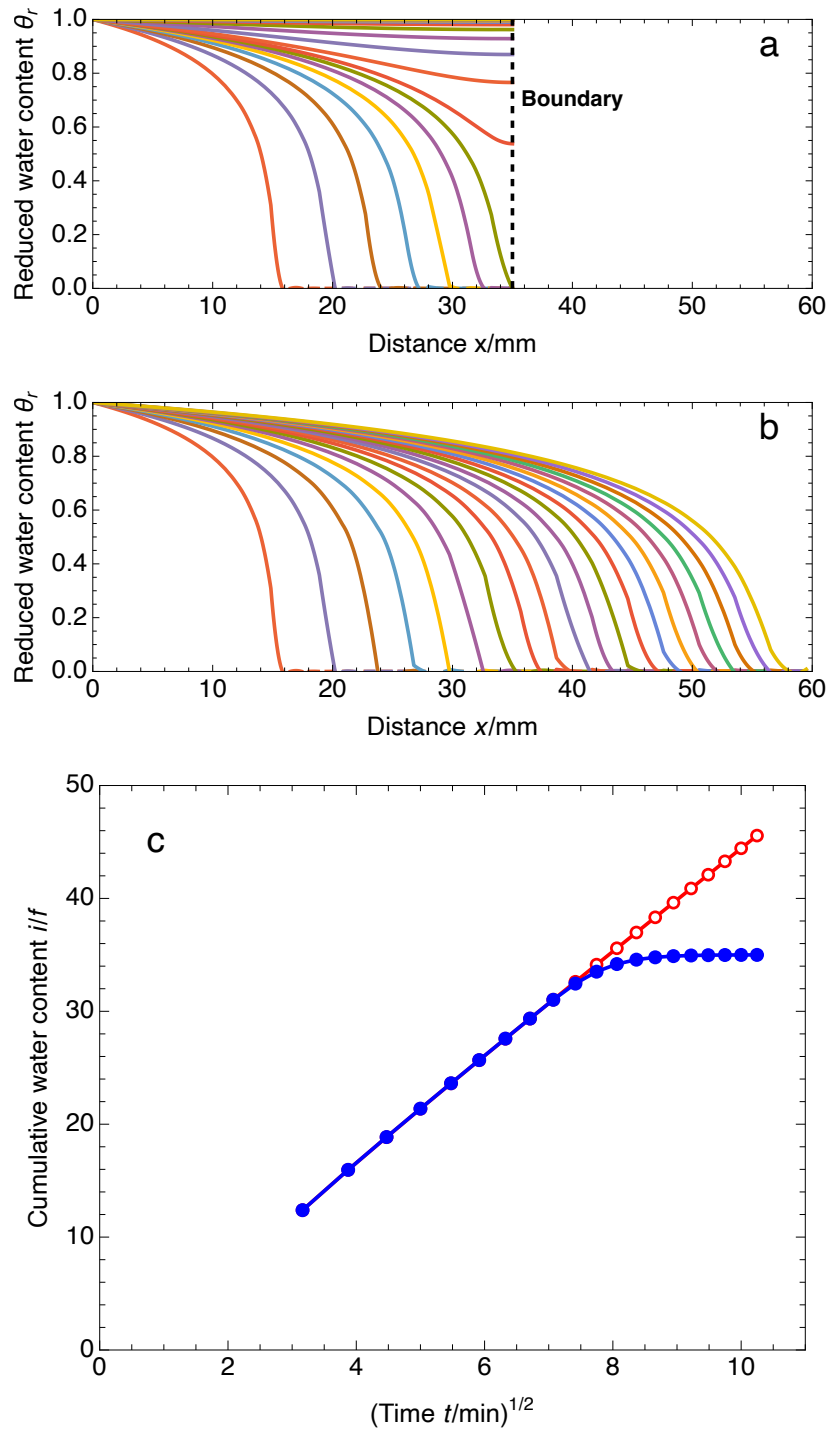
Figure NQ1-1: 1-D water absorption into a uniform porous material. (a) Water-content profiles $\theta_r(x)$ at times 10–105 min at 5 min intervals, finite bar of length 35 mm; (b) Semi-infinite bar (unlimited length); (c) Cumulative water absorption i/f for the finite bar (blue filled circles) and the semi-infinite bar (red open circles), where f is the volume-fraction porosity, here 0.28.

The cumulative absorption in the finite bar falls below that of the semi-infinite case when the leading edge of the profile reaches the end face, and eventually becomes constant when the entire bar attains saturation (strictly when it reaches the Hirschwald state).

A point of some interest is that the roll-over in the cumulative absorption is gradual rather than abrupt. Only for a Sharp Front diffusivity is there an abrupt halt to the increase in cumulative absorption. For other cases, the roll-over depends on the Brutsaert B_r value. Simulations show that the curvature of the roll-over is roughly proportional to B_r. Whether or not B_r can be estimated from the curvature in experimental datasets remains to be explored. If that is found to be the case, then we can obtain the Brutsaert diffusivity function without needing to measure absorption profiles, since knowing B_r we can calculate D_0 from the sorptivity S, using Eqn 4.7 and Note 4 (p 174) of WT3e.

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17 April 2024