Water Absorption into Construction Materials:  
Comparison of Neutron Radiography Data  
with Network Absorption Models

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Abstract. Two different porous building materials have been previously measured and  
J. Phys. D) using neutron radiography to measure the water front position over time.  
The results from this experimental approach show a similar behaviour to the predictions  
from idealised model structures, in that there is a cross over point where the fastest rate  
of absorption at first favours the finer structure material and at later times favours the  
coarser pore structure material. The computer model, Pore-Cor** is used to generate the  
idealised structures and the absorption of fluid into porous structures follows a Bosanquet  
wetting algorithm for fluids undergoing both inertial and viscous dynamical flow  
The model structures comprise cubic pores connected by cylindrical throats on a three-  
dimensional $10 \times 10 \times 10$ position matrix simulating the void structure of porous media by  
fitting as closely as possible the modelled mercury intrusion curve to that of the experi-  
mentally determined mercury intrusion curve of the actual sample. They show the transition  
that occurs in the absorption behaviour from the linear $t$-dependent short timescale  
inertial regime to the familiar $\sqrt{t}$ Lucas-Washburn viscous regime. The simulated absorption  
algorithm applied to these model structures also shows a fluid position behaviour  
that replicates qualitatively, given the limitation of representative sample volume, the cross  
over seen experimentally. Furthermore, the existence of a preferred wetting path is demon-  
strated in the experimental as well as the model wetting front behaviour. In the case of  
the structure containing the broader range of pore sizes, the wetting front is considered to  
proceed by a network of optimal size combinations (inertial wetting versus viscous drag)  
and connectivity, leaving some pores behind the wetting front unfilled or only partially  
filled.

Key words: absorption into building materials, porosity of structural materials, liquid  
transport in porous media, modelling porous materials, preferred pathway flow.

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** Pore-Cor is a software program of the Environmental and Fluids Modelling Group,  
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1. Introduction

Fluid flow through porous media is of great importance in many areas ranging from agriculture through civil engineering to chemical technology. The penetration of water into building materials is important since many effects that influence the durability of the building structure are mediated by water itself as well as chemical and biological agents transported by it. The rate of imbibition is therefore important for the estimation of the rate of structure degradation and ageing.

The infiltration of liquid and the propagation of the moisture front, $x$, in non-saturated porous media are generally described by a diffusion equation that predicts a scaling law of the type $x/\sqrt{t}$ in one dimension.

The non-classical behaviour of water infiltration in porous materials has been studied by Küntz and Lavallée (2001) and Lockington and Parlange (2003), who find that the anomalous diffusion concept with generalised Fick’s law formulation appears to be a natural theoretical framework suitable for the description of the evolution of the main macroscopic variables during the imbibition. Küntz and Lavallée’s interpretation of the NMR one-dimensional water absorption profiles for fired clay brick and limestone provided evidence that the infiltration front does not propagate as $\sqrt{t}$. They introduced a theoretical model for infiltration based on the assumption of a non-Fickian diffusion mechanism and went on to predict that the $\sqrt{t}$ relation may underestimate the volume of absorbed water by about 30 % after times of 100 hr or greater. Lockington and Parlange present an alternative Darcian explanation that retrieves the earlier advantages of the simple absorptivity test in providing parametric information about the material’s hydraulic properties and allowing simple predictive formulae for the wetting profile to be generated. In contrast Mitkov et al. (1998) had previously proposed a phenomenological approach for describing the dynamics of wetting front propagation in porous media. Unlike traditional models, the approach is based on the dynamic nature of the relation between capillary pressure and media saturation. Gray and Miller (2000) went on to suggest that there were some shortcomings in the proposals argued by Mitlov et al. (2000) concluding that they were incorrect.

It has been shown (Schoelkopf et al., 2000a), that in certain broad pore size distribution structures short timescale inertial wetting competes with retardation, initiating a short-lived linear time dependence for absorption in the finer low aspect ratio pores and simultaneously effectively a delay of entry into the larger pores. This behaviour, short lived in each pore element of an interconnected porous medium, together with the longer term viscous drag component, controlled by the average permeability of the structure, is embodied, amongst others, in the solution of the Bosanquet equation, Equation (1), (Bosanquet, 1923), in which momentum considerations form