Study on Water Distribution (Vertical and Horizontal)

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Objectives

- Obtaining information about non-monotonic water saturation distribution and generation of wetting fingers in partially dry soil;
- Investigating the effects of boundary and initial conditions on non-monotonic behavior;
- Studying water redistribution in soil in horizontal direction.

Introduction

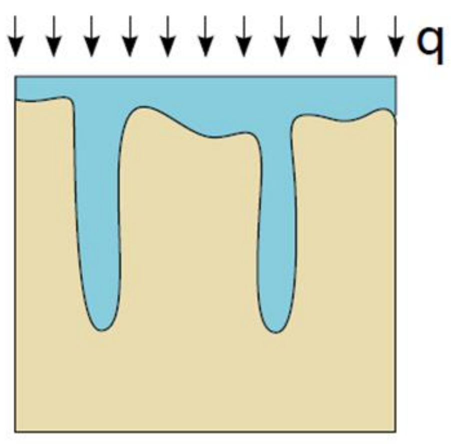

Fig1. Sketch of finger effect

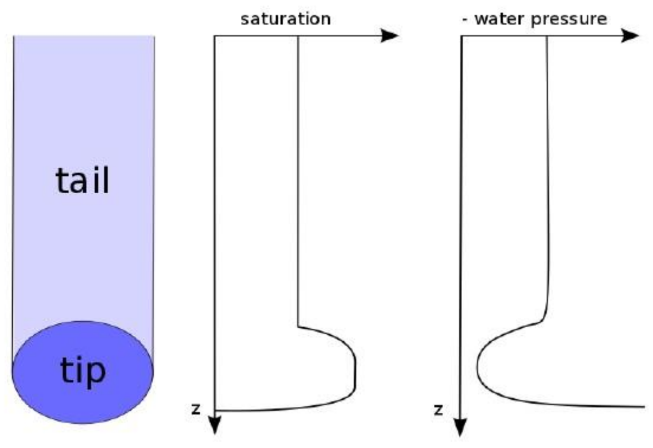

Fig2. Sketch of 1D spatial distribution of a finger,

It is known that when water infiltrates into dry soil, it forms wetting fingers instead of moving as a smooth front (Fig 1).

Moreover, the water saturation and water pressure do not very monotonically along these fingers but they show maximum values at the tip of the fingers (as shown in Fig 2). This overshoot behavior can't be explained and modeled by the traditional Richards equation. Theoretical studies have shown that a non-equilibrium capillarity theory is able to simulate such behavior.

In this study, experiments showed the formation of fingers and overshoot in pressure and saturation.

sand	K(m/s)	ϕ	D_{50}(mm)
PaP-03	5.61e-03	0.40	0.79

Table1. Sand parameters

Dual energy gamma system

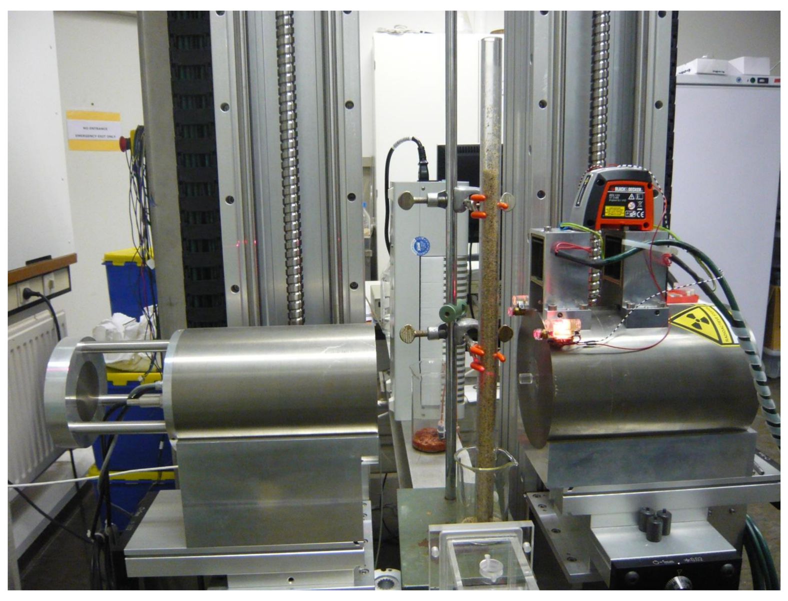

Fig3. The picture of gamma system

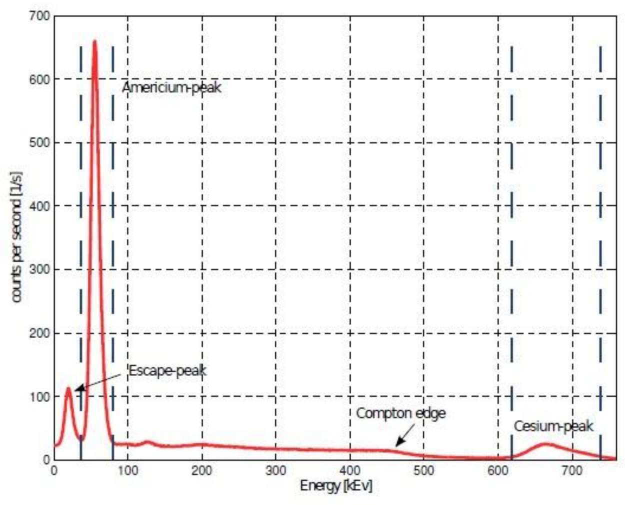

Fig4. Characteristic curve for gamma system

To measure saturation, gamma transmission method was used. Intensities could be detected, while two radioactive sources Ce and Am pass through a sample. The attenuation caused by adsorption of matter between source and detector can be described by Beer-Lambert Law:

$$I_i = I_{0i} \times e^{-\mu_i x}$$

μ_i----linear attenuation coefficient [1/cm]
I ----measured intensities [1/s]
I_0----reference intensities [1/s]
i ----Americium, Cesium

1-D column experiment

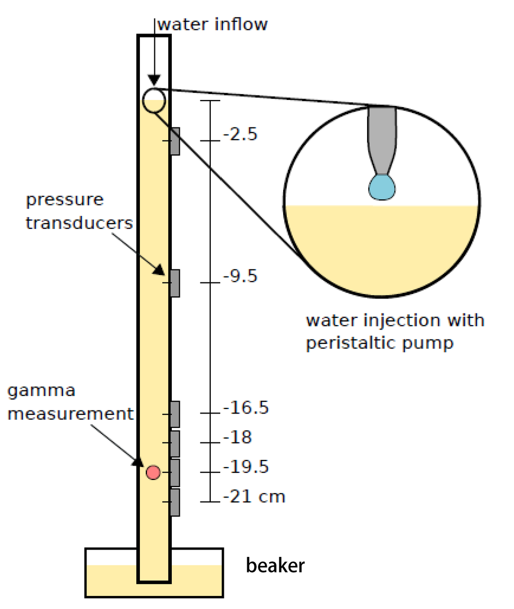

Fig5. Experimental setup

Clean sand was uniformly packed into a glass column of 50cm long and 1cm in diameter. Initial water saturation was 0, 0.03 or 0.1. Water was delivered to the top of a vertical column at different flow rates. Saturation was measured at z=22.25cm. Pressure transducers were installed at six positions along the column.

Results

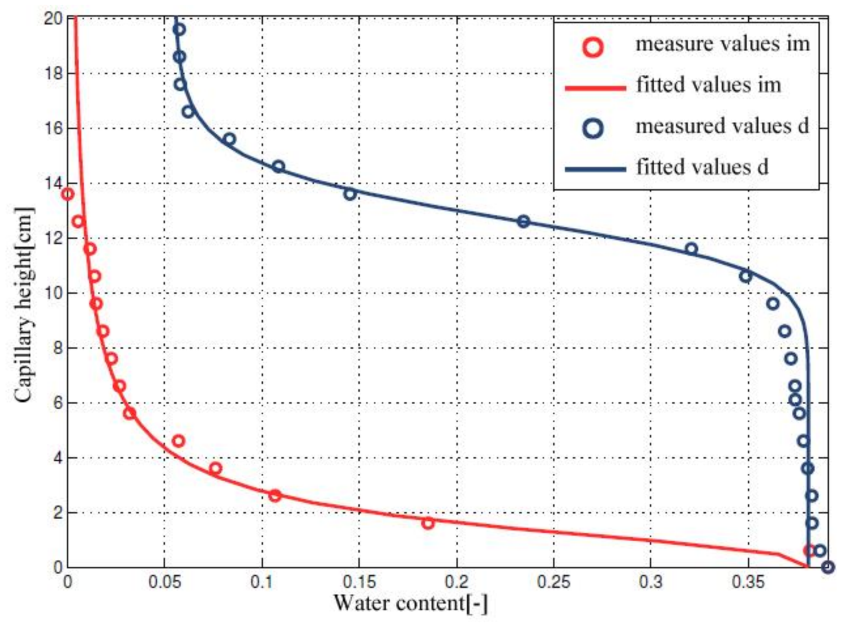

Fig6. Fitting θ to p_c

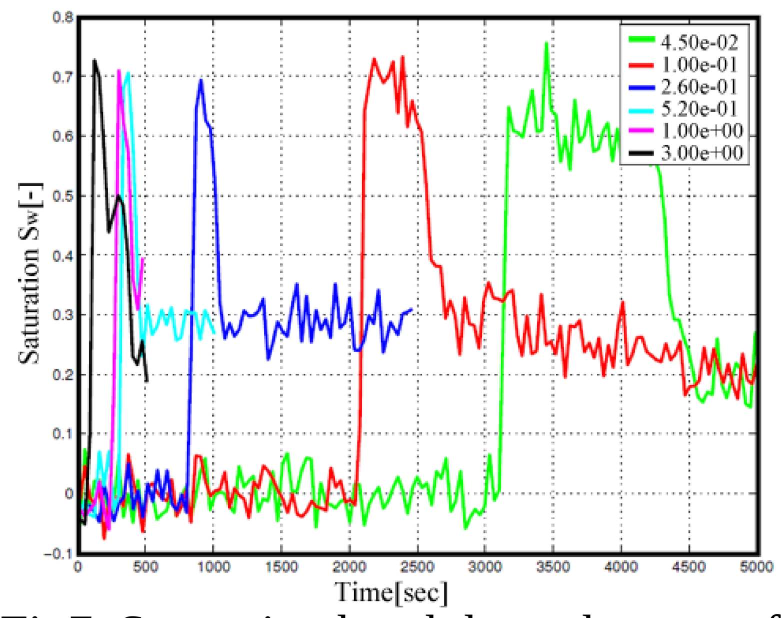

Fig7. Saturation breakthrough curves for different flow rates in cm/min, S_{init}=0

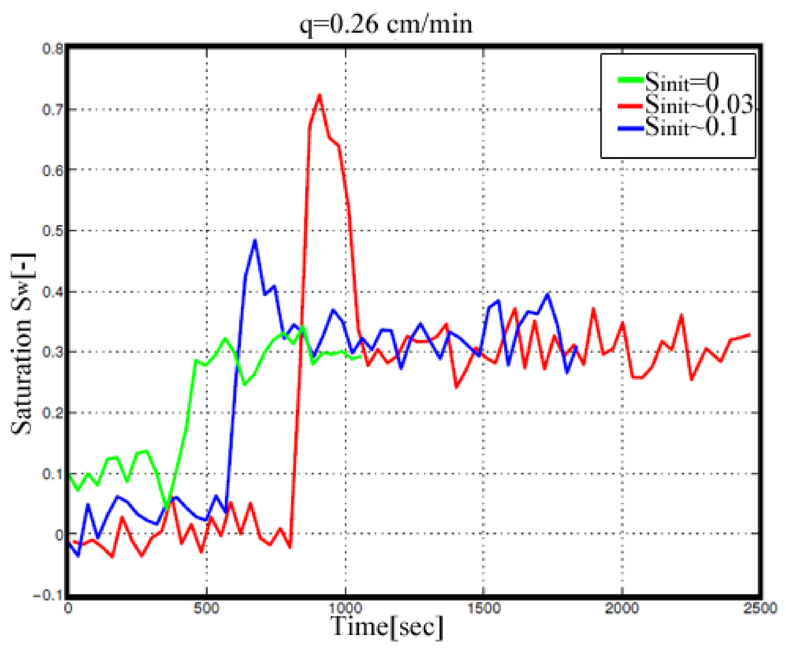

Fig8. Saturation breakthrough curves for different initial water saturation

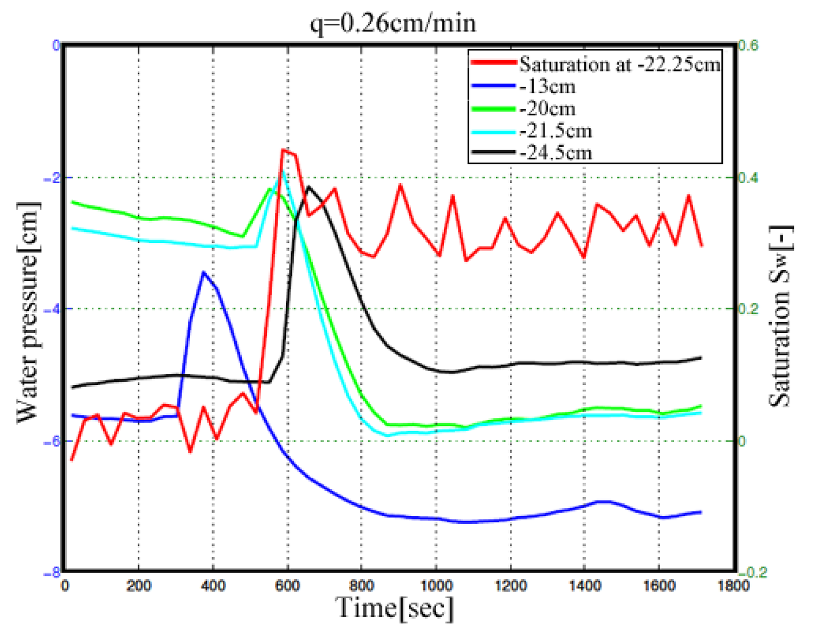

Fig9. Distribution of saturation at one position and pressure at multi-positions

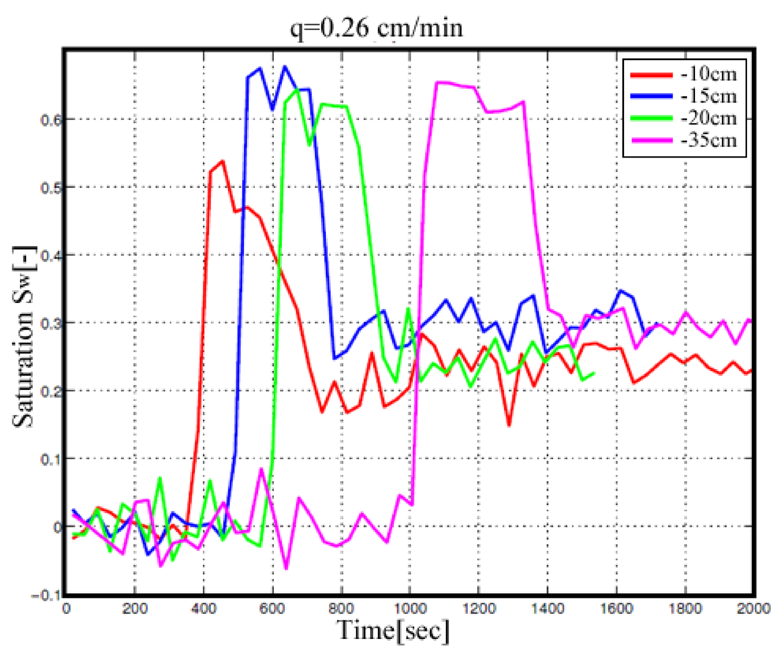

Fig10. Breakthrough curves at different positions with equivalent flow rates

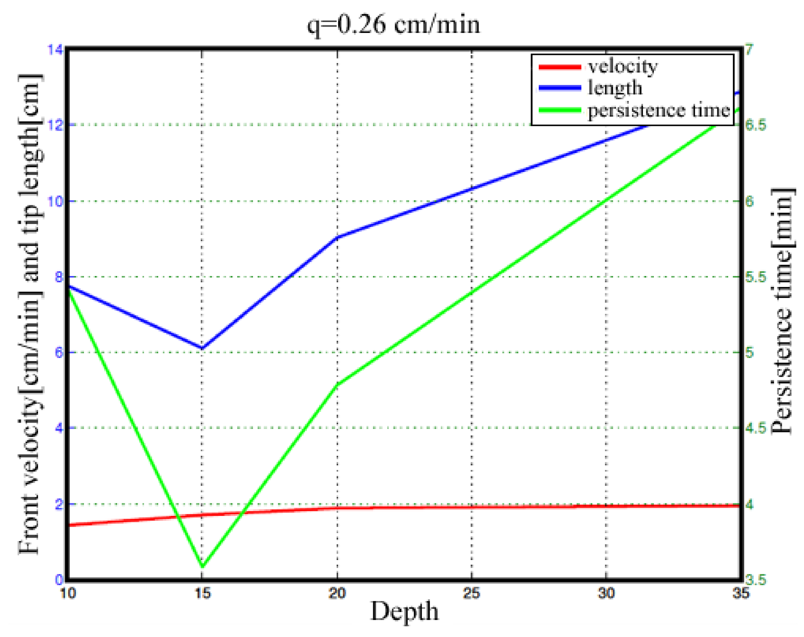

Fig11. Front velocity and characteristic length of the tip

Estimating the tip length by $l_{tip}=t_p v_f$, in which t_p donates persistence time (getting from Fig10.) and v_f is front velocity.

Conclusions

- The tips for small flow rates show distinct plateau structure, while the fast flow rates exhibit only sharp peaks.
- The overshoot decreases for larger initial water saturation and vanishes at residual water saturation.
- Pressure and saturation both are non-monotone, getting to a sharp inclination point and then decreases.
- From a certain position, finger tips flatten and widen over time and depth.

Future work

- Infiltration of water into partially-dry sand in a sandbox.
- Redistribution of water in a horizontal flume.