Effect of Grain Sizes of the Porous Media in Dispersion

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INTRODUCTION

The movement of solutes through soils has been attracted the attention of agriculturists, hydrologists and environmentalists. Many efforts have been devoted in the past few decades to understand the mechanisms of solute transport through the porous media. Dispersion causes the solutes moving with water to spread within soil solution. The objectives of this research is to see the effect of grain sizes on dispersion under unsaturated and saturated conditions. Miscible displacement studies were thus carried out using three different sizes uniform glass beads media for this purpose. Electrical conductivity was used as a tracer.

EXPERIMENTS AND ANALYSIS

Experimental column was made up of PVC rings having 5 cm inside radius and shown in Fig. 1. The column was filled with glass beads. The NaCl solution of a given conductivity was applied over the media using a distributor and a suction was applied from the bottom to get the moisture content inside the media uniform. Steady state condition was established by applying a constant rainfall over the media until the input rate from the top of the media was equal to the outflow rate from the bottom. When the steady state flow condition was attained, another NaCl solution with higher electrical conductivity was applied as a displacing solution at the same rate using another distributor. Electrical conductivities monitored by the probes installed in the column at 20, 30, 40, 50 and 60 cm from the top media surface were recorded in the computer. Saturated experiments were also conducted in the same manner except applying rainfall from the distributor, a certain head was maintain at the top of the media using Marriot tanks and at the bottom, an overflow tank was used at a certain head to get different hydraulic gradients.

The mean pore water velocity(v) was determined by calculating the mean travel time taken by the solution to reach a certain location, using breakthrough curves(BTC). Dispersion coefficient was estimated by fitting the observed data to the analytical solution of one dimensional advection dispersion equation (see Rose and Passioura, 1971) using calculated pore water velocity. Fitting was obtained to minimize the sum of the square of the difference between observed and analytical solution of all probes.

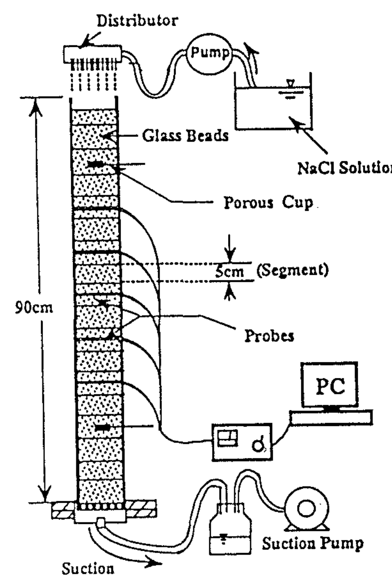

Fig. 1 Experimental set-up

RESULTS AND DISCUSSION

Dispersion coefficients obtained from a number of experiments under unsaturated and saturated conditions for each media are plotted against pore water velocities in Fig. 2a and 2b respectively. Fig. 2a,b show that dispersion coefficient, is increasing as a linear function with increasing pore water velocity in both cases. Dispersion coefficient however found larger in larger grain size media than in the smaller size media for the same pore water velocity. For the same grain size media, gradient is greater in unsaturated condition than saturated one.

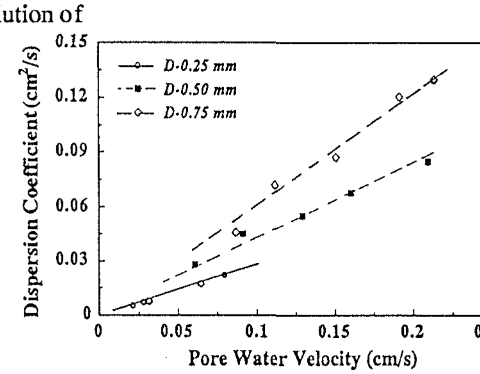

Fig. 2a Unsaturated dispersion coefficients and pore water velocities relationships

Matsubayashi et al. (1995) considered the dispersion process through porous media similar to the turbulent mixing in surface water flow. They thus applied mixing length theory concept to describe the dispersion phenomena inside the porous media also. According to this theory, dispersion coefficient can be expressed as:

$$D = \sigma l \tag{1}$$

where, σ and l are the standard deviation of the pore water velocities and mixing length of the flow paths inside the porous medium respectively.

Pore water velocity distribution inside the porous media were determined from ψ-θ and K-θ relationships. The σ and v values were then estimated for three grain size media used in miscible displacement experiments (see Matsubayashi et al.(1995) for extensive method of determining σ and v). The plots of σ against v given in Fig. 3 shows that σ can be linearly related to v as:

$$\sigma = \lambda v \tag{2}$$

Thus D can be expressed as:

$$D = \lambda l v \tag{3}$$

The gradient λ obtained from σ-v relationships are 1.028, 1.022 and 0.981 respectively for 0.25 mm, 0.50 mm and 0.75 mm grain sizes. In Fig. 4 mixing lengths obtained, using eq.(3) under unsaturated and saturated conditions are plotted against particle sizes. It shows that mixing lengths are almost constant for a given grain size media in considered lower range of moisture contents (<0.27). The average mixing length in this range is about 0.23 cm, 0.40 cm and 0.59 cm for the grain size of 0.25 mm, 0.5 mm and 0.75 mm respectively. Similarly, mixing lengths are almost constant for a given grain size media in saturated conditions also. The average mixing length are 0.048 cm, 0.089 cm and 0.134 cm for the grain size of 0.25 mm, 0.5 mm and 0.75 mm respectively. These results show that mixing length is a function of grain size of the porous media i. e., mixing length is increasing with increasing grain size of the media. This is because solute has to travel a larger distance before meeting one water path with another one in the case of larger grain size. If we look the mixing lengths for a particular grain size media in saturated and unsaturated conditions, unsaturated mixing length is higher than saturated one. Under saturated condition adjacent water paths are close to each other and mixed after moving a small distance while in unsaturated case to meet the adjacent water paths water particle has to travel more. This results in the higher mixing length in unsaturated cases than in saturated cases. The dispersion coefficient therefore is smaller in saturated condition than in unsaturated condition. The ratio of the mixing length under unsaturated condition to saturated condition for a particular media was found about 4.5.

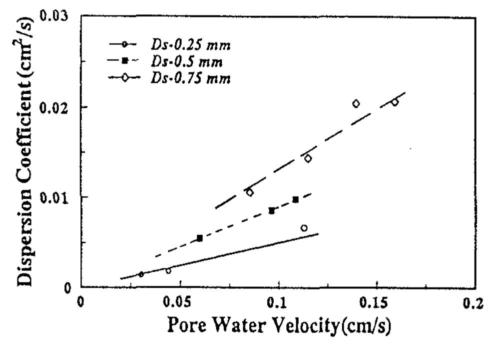

Fig. 2b Saturated dispersion coefficients and pore water velocities relationships

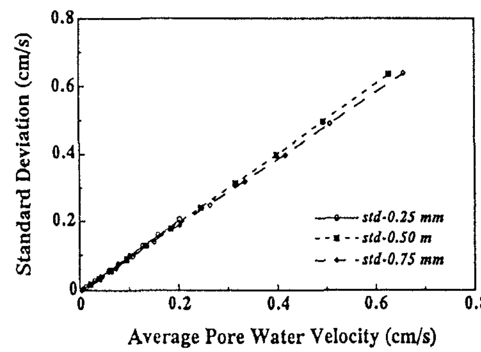

Fig. 3 Relationships between standard deviation and pore water velocities of three media

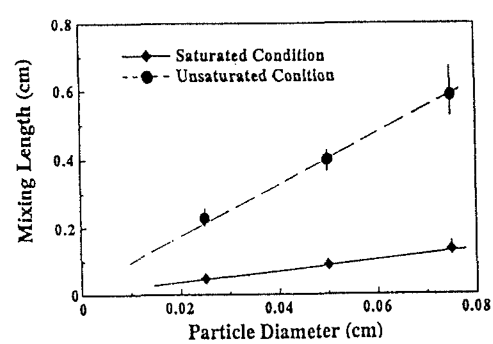

Fig. 4 Relationship between mixing length and grain size of the three media

CONCLUSIONS

The results obtained from this study through uniform grain size media are as follows:

1. For a given size of porous media, the mixing length was found almost constant, one each for unsaturated and saturated conditions.
2. Mixing length was found increasing with increasing grain size.

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Key words: porous media, dispersion, mixing length, pore water velocity distribution.