LABORATORY TESTING OF CAPILLARY RISE IN FINE-GRAINED SANDS AND SILTS

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Introduction

Data for the height of capillary rise in fine-grained sands, silts, and clays, is inconclusive. The literature gives a wide range of values and equations. One source (Applied Hydrogeology, 3rd ed., C. W. Fetter, p. 182) claimed that the height of capillary rise varies from 100 cm in fine-grained sand up to 750 cm in fine silt. We found these numbers unbelievable, and asked the late C.W. Fetter to put better numbers in his 4th ed. Instead, he deleted the table in the 4th ed. The equation which generated his numbers was used by Adamski et al. (2005)* to explain free product accumulations of up to 520 cm in wells.

Our goal was to measure capillary rise in fine sediments, and use our data to identify believable equations and values in the literature for sands, silts and clays.

Silt-sized particles called silica flour and/or uniform sand grains 0.45-0.55 mm in diameter were carefully packed into tall 5-cm diameter glass columns (Fig. 1). These were placed into clear water tanks, with water kept at a constant level (Fig. 2). The height of tension-saturated capillary rise observed above the constant water level was measured in each experiment (Fig. 4).

Experiments

Some of the fine sand was treated with a water-repellent spray (Kiwi Camp Dry) to test capillary rise in a hydrophobic porous medium. This was done to show the effects that wettability has on capillary rise. The capillary fringe in our hydrophobic sand columns was suppressed below the free water level in the tanks (Fig. 5). The glass columns and tanks were cleaned between experiments to avoid cross-contamination from the water-repellent chemicals.

Measurements of capillary rise in silts with average grain size below 40 microns were made in the same glass columns and water tanks. Capillary rise reached the tops of the columns, which were 142 cm high. Columns were extended by 122 cm by screwing a 4-ft glass column onto a hollow threaded teflon piece (visible halfway up column in Fig. 1). The silt compacted and cracked when wet, leaving gaps (Fig. 3). Later tests used silt mixed with equal volumes of fine sand. There was much less compaction and cracking, and fewer gaps in these later experiments. The presence of sand in the mixture will have little effect on capillary rise, because silt fills in between the sand grains and capillary rise is determined by the properties of the smallest interconnected pores.

Results and Conclusions

In five fine sand columns the average height of tension-saturated capillary rise was 7.9 cm, average height of damp unsaturated sand above that was 19.5 cm, and average density was 1.61 g/cm3.

In four hydrophobic sand columns, the average depression of the saturated zone was 5.75 cm and average density was 1.57 g/cm3.

In four silt columns, the average height of the tension-saturated capillary fringe was at least 147.3 cm. Large horizontal cracks in the columns of silt may have affected testing. The hydrophobic inner surface of the teflon joining piece may also have affected the tests. Improved testing is necessary to ensure that capillary rise in the silt columns has reached its ultimate value.

References

Adamski, M., V. Kremesec, R. Kolhatkar, C. Pearson and B. Rowan, 2005. LNAPL in Fine-Grained Soils: Conceptualization of Saturation, Distribution, Recovery, and Their Modeling, Ground Water Monitoring & Remediation, 25, no.1, 100-112.

Fetter, C. W., Applied Hydrogeology, 3rd ed., 1994, Macmillan, and 4th ed., 2001, Prentice-Hall.

Figures

Fig. 1: Packing silt column

Fig. 2: silt and sand columns

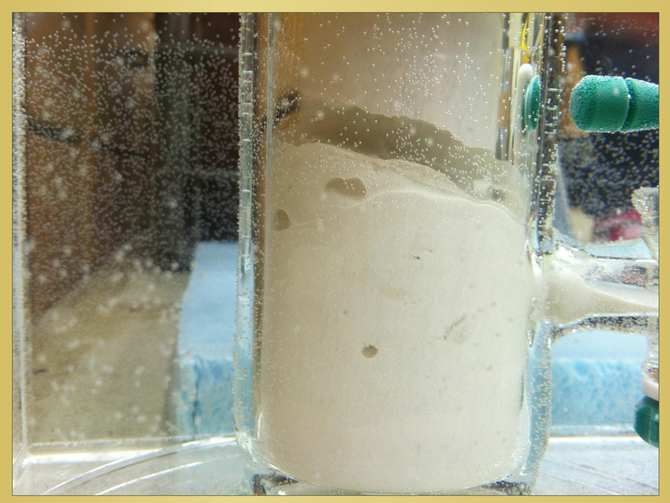

Fig. 3: cracking in wet silt

Fig. 4: measuring capillary rise

Fig. 5: measuring capillary depression