FINE PARTICLE CLOGGING IN DRAINAGE LAYERS

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Abstract

This paper addresses permeability reduction due to fine particle clogging along drainage layers using experimental study. Non-uniform concrete sand and uniform Ottawa sand were used as the drainage layers that were permeated by particle suspensions of kaolinite. It was observed that permeability reduction due to particle clogging changed temporally and spatially — permeability reduces more in upstream than in downstream with time. Finer grain segregation was observed during sample packing in concrete sand and greater permeability reduction occurred in the segregated section.

Introduction

Adequate subsurface drainage is a key factor controlling the level of serviceability of many infrastructures. Excessive moisture that accumulates due to reduced permeability beneath a foundation or a pavement structure can result in excessive pore water pressure and ultimately destruction of the structure. Previous investigations (Gruesbeck and Collins, 1982; Baghdlklan et al., 1989; Reddi et al., 2000) were carried to study the effects of the naturally occurring fine particles on the permeability of porous media. They observed that the entrainment and deposition of fine particle suspensions in porous media led to abnormal decline in permeability. Reddi et al. (2000) noticed more than one order of magnitude of permeability reduction in experiments due to the clogging of polystyrene and kaolinite particles in the pore stream with concentrations of 0.5 to 1.0 g/liter. Colloidal particles in runoff may remain in suspension and may be transported long distances. Fine particle clogging could happen anywhere in a drainage layer where the conditions are suitable. Previous literature (Baghdiklan et. al., 1989; Characklis and Wiesner, 1997; Reddi et al., 2000) that were devoted to fine particle transport and deposition in porous media contributed to the understanding of the influences of particle size, physical properties of fluids, and fluid velocity on permeability reduction. Few studies, however, reported the variation of particle clogging and permeability reduction in different locations of the same drainage layer. This paper reports the investigation results of the permeability reduction in different sections of a drainage layer due to fine particle clogging.

Experimental Materials and Method

Two types of sandy soils (concrete sand from a local concrete manufacturer and sieved Ottawa sand with narrow grain sizes of 0.5mm to 0.6mm) were used as drainage
layers in this study. Their grain size distributions are shown in Figure 1. Kaolinite was used as the particulate suspension to permeate the soil samples. The size distribution, obtained using a Coulter particle analyzer, is shown in Figure 2. The Coulter analyzer employs an electrical impedance method to determine accurate particle size distributions and particle population numbers within the size range of 0.4 to 1200 microns.

An experimental setup (Figure 3) was devised for this investigation. The influent was prepared in a suspension tank at a desired particle concentration. To keep the suspension stable and uniform in the tank, two electrical stirrers were used in the entire duration of the experiment. The particle suspension was pumped into the soil sample using a programmable flow pump at a desired flow rate. The flow pump was calibrated for the flow rate (100ml/min) used in this study. A pulse dampener was used between the pump and the sample to absorb the pulses generated by the pump. The sample column (30cm in length, 5cm in inside-diameter) was connected with four pressure gauges, which divided the soil sample into three sections of equal length. The soil column was prepared using Ottawa sand or concrete sand. Given the porosity (Ottawa sand; 0.382; concrete sand: 0.285), the volume of the
Sieved Ottawa sand was first used as the drainage layer. The permeability reductions of the upstream, mid stream, and downstream sections of the drainage layer were shown in Figure 4. The upstream section yielded the largest permeability reduction, as the influent particle concentration was the highest. The middle section of the soil sample had less permeability reduction, because the migrating particle concentration decreased due to partial particle deposition in the upstream section. The downstream section had the least permeability reduction. It was also noticed that during the first 40

![Figure 4. Permeability reduction due to particle clogging in Ottawa Sand drainage layer using Kaolinite particles](image)

![Figure 5. Permeability reduction due to particle clogging in concrete sand drainage layer using Kaolinite particle suspension](image)

**Results and Discussion**

column, and the specific gravity (2.65 for both sands), the soil mass was calculated (Ottawa sand: 1004g; concrete sand: 1160g). The sandy soil was carefully poured into the column during the preparation of the soil sample. While being filled with sand, the soil column was shaken slightly in order to hold the entire calculated soil mass in it.

In each experiment, before using the particle suspension, de-aired water was used to obtain the initial permeability of the three sections of the drainage layer. This also ensured accurate working of the various segments of the experimental setup. During the experiment, the four pressure gauge readings were taken at fixed time intervals, and the permeability of the three soil sections was calculated using the Darcy’s law.
minutes, the permeability of the downstream section did not reduce, because at the beginning of the experiment the upstream and middle sections had the greatest ability to filter the suspensions. Figure 5 illustrates the results from a representative experimental run of the concrete sand. The results indicate that during the initial 250 minutes, despite that the particle concentration in downstream section was less than that in the upstream due to particle filtration, the permeability of downstream section reduced more than that of the middle section, as opposed to the results shown in Figure 4.

The greater permeability reduction in the downstream section than in the upstream section may be accounted by two mechanisms — segregation and self-filtration. During the preparation of the concrete sand soil sample, it was noticed that the downstream section contained several segregated finer layers, and the kaolinite particles were significantly filtered in these finer segregated layers, reducing the permeability more than that in the middle section where no segregation was visually observed. Self-filtration is a phenomenon that finer grains of the upstream sandy soil are entrained by the pore fluid at a high flow rate and then are entrapped in downstream section, reducing the permeability of downstream section. Self-filtration was observed and discussed in the experimental investigation of soil filter clogging by Reddi et al. (2000).

Conclusions

This experimental study investigated the effect of grain size distribution of sandy soils on the particle clogging and permeability reduction in drainage layers. With constant suspension source, particle clogging in a long drainage layer changes temporally and spatially. Permeability generally reduces more in upstream than in downstream due to more particle entrapment in upstream and the resulting less particle concentration in downstream drainage layer. Grain segregation may occur in non-uniform sandy soils, and segregated finer layers in a drainage system affect the rate of particle clogging and permeability reduction. It is suggested that particle clogging, governed by characteristics of sandy soils and migrating particles in runoff, should be considered in the design phase for a predictable lifetime behavior of drainage systems.

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References