Effect of salt solution on the permeability on compacted sand-bentonite mixture

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Introduction

Clay liners containing bentonite are frequently installed at waste disposal sites as a means of preventing pollutant migration and minimizing or eliminating the potential for ground water contamination, due to low permeability and contaminant sorption ability of the bentonite.

Bentonite is susceptible to undergo change in their properties when a salt solution is permeated through it. In the present work we have tried to study the effect of the salt solution on the permeability of the compacted sand-bentonite mixture.

Materials and Method

For the present study a high swelling smectite of bentonite clay (Hodaka, Hojun Kogyo Ltd, Japan) and Toyoura standard sand of average size 0.5mm was used. The CEC of the bentonite was 65.8cmol/kg. Clay-sand mixture containing 5% clay by weight was mixed at a water content of 2% wet of optimum. Then a falling head hydraulic conductivity test was carried out at different load to ascertain the load corresponding to a hydraulic conductivity value of 10^{-6}cm/sec. All the tests were carried out at a hydraulic gradient of 20 using consolidation cell of 6cm diameter and 2cm height. Then the data was plotted between the hydraulic conductivity and the applied pressure. From the graph it was found that the overburden pressure of 12.8 kg/cm^2 corresponds to a hydraulic conductivity of 10^{-6} cm/sec.

The clay and sand were mixed at 2% wet of optimum water content and allowed to equilibrate in a desiccators for 24hrs.Then the moisture equilibrated soil was statically compacted in the consolidation ring at maximum dry density. Then a variable head saturated flow experiment was carried out with the soil specimen at an overburden pressure of 12.8kg/cm^2. Two different salt solutions of NaCl and $CaCl_2$ were chosen for the study. Initially 0.5M salt solution of about 5 pore volume was supplied to all the four specimens and then less concentrated solution of 0.1M, 0.05M, 0.01M, 0M (distilled water, DW) were permeated to the specimens respectively until the salt concentration in the effluent becomes constant. Each solution was supplied for more than 10 pore volumes of the sample. A hydraulic gradient of 20 was applied to the entire specimen. Volume of the specimen was kept constant during the permeability test. The effluent solute concentration was measured with the ion chromatograph.

Results and Discussion

(i) Effect of Na^+ ion on hydraulic conductivity

Figure1 shows the change in the hydraulic conductivity (HC) with the number of pore volume passing through the soil sample. Prior to the permeation of the solution of different salt concentration, 0.5M NaCl solution of 5 pore volume was supplied to the whole specimens. By the supply of this solution the HC increased from the initial 10^{-6}cm/sec to the values at zero pore volume in Fig.1 for the respective salt concentration. In Fig 1, with increasing the pore volume the HC decreased for any salt concentration, but the HC at a given pore volume was affected by the salt concentration. At the final pore volume the specimen of higher salt concentration gave a higher HC value except for the water. During the permeation with water, dispersed bentonite particles moved out from the specimen, which prevented the HC from being reduced. The reduction of the HC due to the decrease of salt concentration can be attributed to the expansion of diffuse double layer of bentonite clay particles.

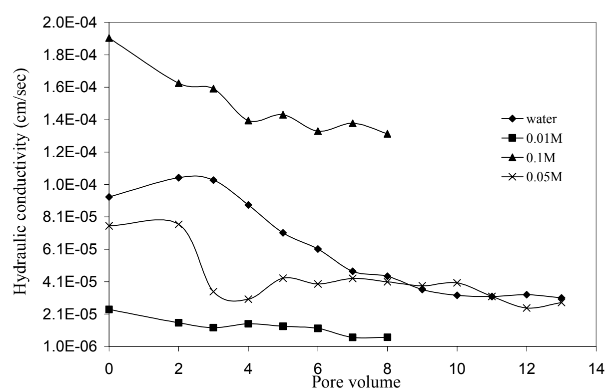

Figure 1. Change in hydraulic conductivity with permeation of NaCl

Figure 2 shows the variation of the Na^+ concentration

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of the effluent with the number of pore volume. It shows that at first the Na^+ concentration decreases rapidly up to around 8th pore volume. It almost remains constant for further pore volume and the final Na^+ concentration roughly accorded with that of the influent.

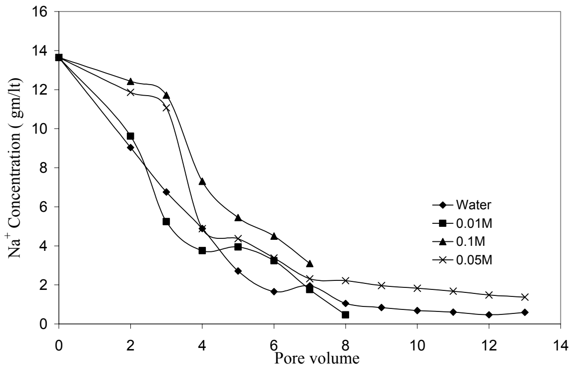

Figure 2. Change in concentration of effluent with permeation of Nacl

(ii) Effect of Ca^{2+} ions on hydraulic conductivity

Figure 3 shows that the change in the hydraulic conductivity (HC) with the number of pore volume passing through the soil sample. The change in HC due to permeation of $CaCl_2$ was less as compared to the permeation of NaCl solution in Fig. 1. When the HC values at the final pore volume are compared, the HC for water was much lower than that for other salt concentrations. The HC for 0.05M and 0.01m of $CaCl_2$ solution was higher than the HC for the same concentration of NaCl solution (Table 1). This can be attributed to the depression of the diffuse double layer of bentonite clay particles in the $CaCl_2$ solution.

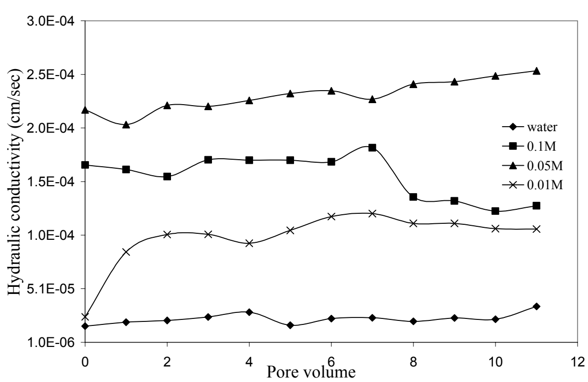

Figure 3. Change in hydraulic conductivity with permeation of $CaCl_2$

Figure 4 shows that at first the Ca^{2+} concentration decreases rapidly and after the 5th pore volume it remains constant, being equal to the influent salt concentration.

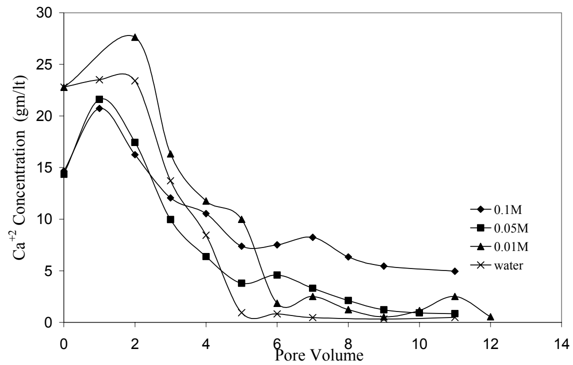

Figure 4. Change in concentration of effluent with permeation of $CaCl_2$

Table1.Hydraulic conductivity at final pore volume

Salt concentration	NaCl (cm/sec)	$CaCl_2$ (cm/sec)
0.1M	1.32×10^{-4}	1.28×10^{-4}
0.05M	2.81×10^{-5}	2.54×10^{-4}
0.01M	6.72×10^{-6}	1.06×10^{-4}
0M (DW)	3.1×10^{-5}	3.44×10^{-5}

Conclusion

The hydraulic conductivity (HC) of the compacted sand-bentonite mixture increases dramatically by the supply of 0.5M NaCl and $CaCl_2$ solutions. With subsequent permeation of less concentrated salt solutions, the HC is kept the same for 0.1M NaCl and the whole $CaCl_2$ concentrations while the HC decreases for the lower NaCl concentrations than 0.05M. These results indicate that the HC of the clay liner mixed with bentonite heavily depends on the type and concentration of the salt in the permeate liquid, and the high concentration NaCl and the whole concentration range of $CaCl_2$ enhance the HC of the mixture.

References

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