Chemico-osmotic behaviour of an organically modified "Multiswellable" bentonite

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Introduction

A modified "multiswellable" bentonite (MSB) obtained by treating natural sodium bentonite with an organic polymer has been studied. The MSB exhibited higher swelling capacity and lower hydraulic conductivity than untreated bentonites for $CaCl_2$ solutions up to 0.5 mol/L (Katsumi et al., 2001).

Therefore, in view of pollutant containment applications, it is interesting to evaluate the potential for chemico-osmotic behaviour of MSB.

Table 1. Physical and chemical properties of MSB

Property	MSB
Trade name	MULTIGEL
Main mineral	Montmorillonite
sample porosity (	0.717
sample unit dry solids	4.5 kg/m^2
pH	7.0 - 8.0
EC	188 µS/cm
CEC	52.6 meq/100g
Exch. Cations:	
Na+	41.0 meq/100g
Ca2+	16.9 meq/100g
Mg2+	6.8 meq/100g
Soluble ions :	
Na+	13.5 meq/100g
Ca2+	1.7 meq/100g
Mg2+	0.8 meq/100g
Cl-	1.4 meq/100g
HC03-	8.6 meq/100g
SO32-	3.9 meq/100g

Chemical Osmosis

Chemical osmosis in clayey soils - used in engineered barriers for pollutant containment - is attributed to the overlapping diffuse double layers of adjacent clay particles that limit the migration of charged solutes while allowing the flow of water.

However, chemico-osmotic behaviour may be destroyed if double layers are compressed, as it occurs in the presence of multivalent ions or high electrolyte concentrations (Mazzieri et al., 2003; Shackelford and Lee, 2003).

The steady-state osmotic efficiency coefficient ω can be calculated as $\omega=\Delta(P)/\Delta(\Pi)$, where $\Delta(P)$ = measured differential pressure and $\Delta(\Pi)$ = osmotic pressure difference according to the van 't Hoff's equation.

MSB initially exhibited membrane behaviour, that was gradually destroyed during the test (Fig. 1 a).

The time required to destroy the membrane behaviour correlated well with the time required to reach steady-state diffusive transport of Ca^{2+} ions through the specimen (Fig. 1 b).

Experimental set-up

The experimental set-up consists essentially of two main parts: the testing cell and the pumping system (Fig. 2).

The cell consists of a mould containing the soil specimen and a pressure chamber separated by a rigid piston.

The pumping system is used to circulate solutions of different concentrations at the top and distilled water at the base of the soil specimen in order to induce a chemical gradient across the soil.

Avoiding any fluid flow through the sample, if osmotic behaviour occurs, a differential pressure should be measured.

Hydraulic conductivity

A sample was prepared by spreading a thin layer of dry MSB (0.45 g dry solids/cm^2) into the osmotic cell mould. The mould was then inundated with distilled water (DW) and the MSB allowed to saturate and freely swell. The sample was then compressed until the desired porosity.

Hydraulic conductivity (k) of MSB was measured with DW during the flushing phase and with a 0.005 M $CaCl_2$ solution after the chemico-osmotic test. Finally a permeation with DW was carried out after the pre-hydration with the electrolyte solution (Fig. 3).

The increase of hydraulic conductivity after the osmotic test is consistent with the observed decrease of chemico-osmotic efficiency.

Figure 3. Hydraulic conductivity test results

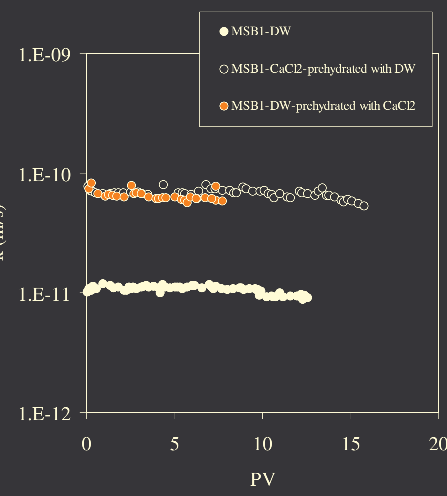
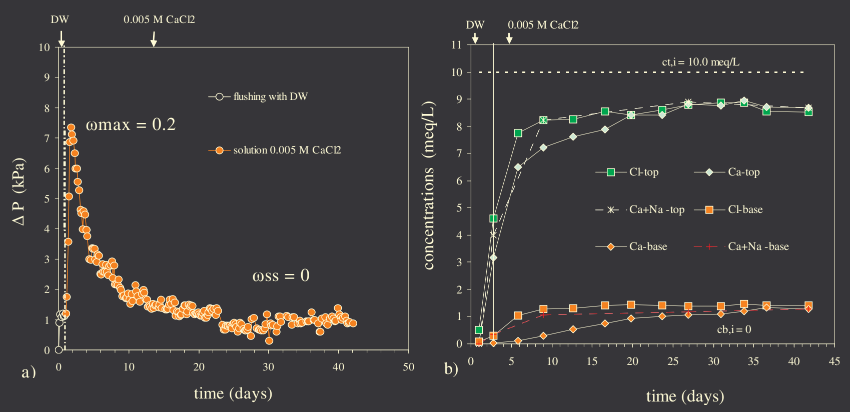


Figure 1. Chemico-osmotic test results: a) differential pressure (ΔP); b) measured outlet concentrations



Conclusions

Test results have shown that MSB did exhibited initial membrane behaviour.

As noticed for untreated bentonites the membrane behaviour of MSB was gradually destroyed as a result of salt migration into the MSB and the consequent compression of the diffuse double layer.

The hydraulic conductivity increased only slightly in the presence of $CaCl_2$, therefore the use of MSB in containment applications appears promising.

Figure 2. a) scheme of the chemico-osmotic apparatus – b) osmotic cell – c) pump and cylinders