Response of fly ash-bentonite based landfill liner to chemical solutions

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Introduction

Hydraulic barriers are a part of lining systems which are responsible for preventing a potential pollutant present in the waste containment from migrating to surface water, groundwater and thus polluting them. Natural clays, calcium or sodium-based bentonite mixed with specific geo-materials are widely used in the construction of hydraulic barriers such as liners and covers due to their low hydraulic conductivity (i.e. $k \leq 10^{-7}$ cm/sec).

In the present study, Sodium bentonite (low sodium content) instead of calcium bentonite was used as the hydraulic conductivity of Sodium bentonite is approximately five times lower than that of the Calcium bentonite at similar void ratios (Mesri and Olson 1971). Chlorides and Sulphates are widely distributed in nature and are common constituents in the leachate (Arasan and Yetimoglu 2006; Yilmaz et al. 2008). The chemical properties of the landfill leachate listed by Kayabali et al. 1998, also showed larger amounts of Cl^-, Na^+, K^+ ions which are exchangeable. Therefore, chlorides and sulphates of different cations such as Sodium, Calcium, and Iron etc. are chosen for the permeation process, which best represents the in-situ conditions in the laboratory. The preference for replacement is the lyotropic series, which is Li^+, Na^+, K^+, Rb^+, Cs^+, Mg^{2+}, Ca^{2+}, Ba^{2+}, Cu^{2+}, Al^{3+}, Fe^{3+} (Sposito 1981; McBride 1994). Because Na^+ is at the lower end of the lyotropic series, Sodium bentonites are more prone to cation exchange when permeated with solutions containing divalent or trivalent ions (Sposito 1981).

Therefore, in the present study, bentonite mixed with fly ash (FA-B) was permeated with different chemical solutions and their chemical compatibility as a liner material was assessed.

Materials and Methodology

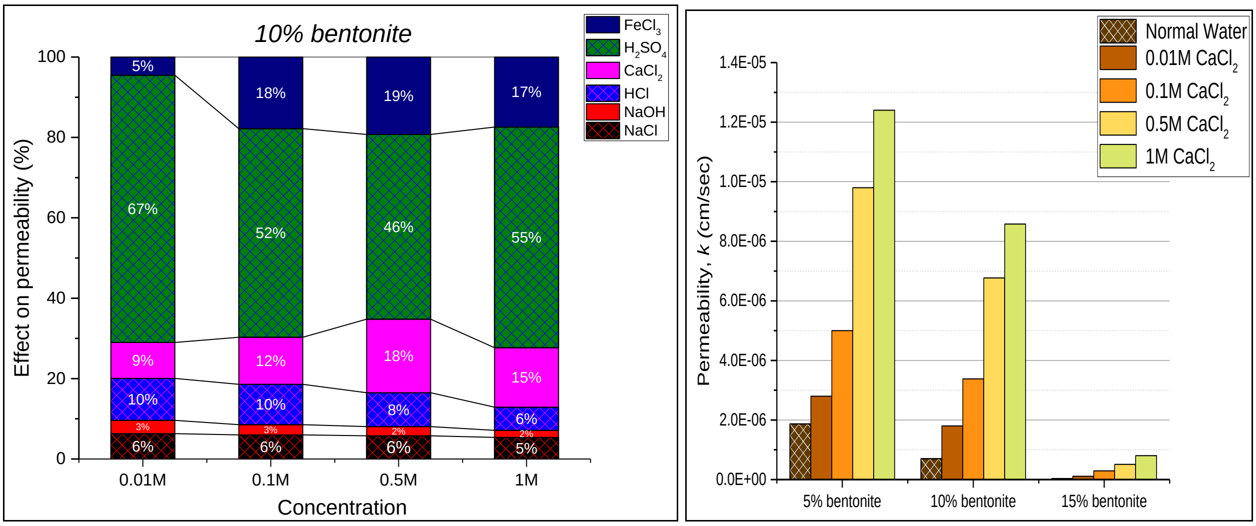
Cohesionless material includes Fly ash collected from Aditya Alumina Ltd. situated in Lapanga town of Sambalpur district, Odisha. Cohesive material includes commercially available sodium based bentonite in the local market. The basic geotechnical characteristics of the materials were found out by performing different laboratory tests (Table 1). In order to assess the chemical characteristics, permeability tests are carried out using a pressure-permeameter, under different heads of 15m, 25m, 35m and 45m of water respectively, on different trial mixes of fly ash and bentonite with different chemicals.

The bentonite content in the fly ash-bentonite mixture is taken up to 15% @ 5% increment starting from 5%. The permeant solutions used include NaCl, NaOH, HCl, $CaCl_2$, H_2SO_4, and $FeCl_3$, which are chosen to best represent the acidic, basic, neutral nature of the landfill leachate as well as to better portray the effect of monovalent, divalent, trivalent cations present in the in-situ landfill leachate.

Results and Concluding Remarks

Table 1. Geotechnical properties of fly ash and bentonite

Property	Fly ash	Bentonite
Specific Gravity	2.08	2.74
Liquid limit, *LL* (%)	-	268
Plastic limit, *PL* (%)	-	54
Linear Shrinkage, L_s	-	29
Plasticity Index, *PI* (%)	-	214
Differential Free Swell Index, *DFSI* (%)	0	400



(a) *(b)*

Figure 2. (a) Effect of concentration and type of permeant solution on permeability of FA-B mixture for 10% bentonite (b) Effect of bentonite content and $CaCl_2$ concentration on permeability of FA-B mixture

Based on the test results of fly ash and bentonite mixtures (i.e. 85:15, 90:10 and 95:05) with six types of permeating solutions (i.e. NaCl, NaOH, HCl, $CaCl_2$, H_2SO_4 and $FeCl_3$) of five different concentrations (i.e. 0, 0.01M, 0.1M, 0.5M and 1M), the following major inferences were drawn.

- Irrespective of the nature of the permeant solution (acidic/basic/neutral), the hydraulic conductivity of all the fly ash-bentonite mixtures increased with an increase in chemical concentrations (Figure 2(b)).
- The net repulsive forces were better supressed by multivalent ions than the monovalent ions, resulting in the flocculation of bentonite particles leading to higher permeability (Figure 2(a)).
- The effect of valence of cation is more at higher concentrations than at lower concentrations i.e., with increase in cation valence the hydraulic conductivity increases and has negligible effect when solutions were dilute (≤0.01M).

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