HCTL Open International Journal of Technology Innovations and Research (IJTIR)
http://ijtir.hctl.org
Volume 14, April 2015
e-ISSN: 2321-1814, ISBN (Print): 978-1-62951-946-3

An analysis of the Swelling Behaviour of Bentonite-Sand Mixtures using Consolidation

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Abstract

Sand is pervious and non plastic in nature. Sand mixed with suitable bentonite content is generally used as a liner material at the waste disposal sites. The swelling behavior of mixture of expansive soils and non expansive soils occurs in three different phases: inter-void, primary and secondary swelling and this is mostly dependent on the mineralogical composition, size and shape of non swelling fraction particles. In the present study, different proportions of sand-bentonite were mixed to determine the swelling behavior at different consolidation conditions. The results indicated that fine sands lead to higher value of swelling and swelling pressure compared to coarse and medium sand.

Keywords

Bentonie, type of sand, swelling, swelling pressure.

Introduction

Sand is a pervious material in nature. The physical properties of bentonite are dictated by the mineral montmorillonite. Montmorillonite has large specific surface area (800 m2/g), high charge efficiency (0.5-1.2 per unit cell), high cation exchange capacity (80-150 cmolc/kg), high swelling potential, and low hydraulic conductivity (Gleason et al. 1997). Compacted clays are usually used as liners because they are very impervious. Hydraulic conductivity of compacted clays is usually less than 1x 10-7 cm/s. To build liners with sand alone is very difficult because of its non-plastic and pervious nature. Generally, hydraulic conductivity of sand is higher than 1 to 1x10-5 cm/s. However, the hydraulic conductivity of sand can be decreased if sand is mixed with a very impervious material such as bentonite (Chalermyanont and Arrykul 2005).

Generally, a mixture of sand bentonite is used as liner material in a landfill site. To achieve a lower hydraulic conductivity, sand bentonite mixtures are compacted at their maximum dry density (MDD) and optimum moisture content (OMC). However, during the construction of liners, it is very difficult to maintain the water content of sand bentonite

mixture at OMC The OMC changes due to loss or gain of moisture due to evaporation or rainfall during mixing, transportation and placing (Coward 1991).

Based on the studies conducted on the swelling behaviour of mixtures of bentonite clay and nonswelling coarser fractions of different sizes and shapes, Sivapullaiah et al. (1996) reported that the observed swelling occurs only after the voids of the nonswelling particles are filled up with swollen clay particles. Kumar and Yong (2002) presented the results of an experimental study conducted on compacted clay-bentonite mixtures to develop data on the effects of bentonite on engineering properties of compacted clay-bentonite mixtures. The laboratory test results indicated that liquid limit, plastic limit, and plasticity index increased linearly with increased amount of bentonite. The addition of bentonite resulted in decreased maximum dry unit weight but the optimum moisture content increased slightly. Sun et al. (2013) studied the swelling characteristics of GMZ bentonite and bentonite–sand mixtures inundated with distilled water using experimental methods.

The test result showed that the relation between the void ratio and the swelling pressure of compacted GMZ bentonite–sand mixtures at full saturation is independent of the initial conditions such as the initial dry density and initial water content, and dependent on bentonite/sand ratio. Saba et al. (2014) studied the swelling pressure of a small scale compacted disk of bentonite and sand experimentally in both radial and axial directions. From literature it is observed that there are very few studies where the characteristics of bentonite sand mixtures have been analysed with its specific usage as land fill barriers. In this paper, the swelling behavior of bentonite sand mixture is studied using consolidation studies.

Materials and Methods

Two types of soils (bentonite and sand) are using in this study as a liner material, and these soils are mixing in different proportion to assess the behavior of compaction characteristics (OMC & MDD), swelling, hydraulic conductivity and compressibility. Therefore, different sand-bentonite mixtures were prepared as listed in Table 1. The objective of this study is maximum utilization of sand-bentonite mix as a liner material.

Table 1 Designation of sand-bentonite mix used in this study

Soil mix	Soil mix
% of Bentonite(B) + % of Fine sand (FS)	10%B+90%FS
	20%B+80%FS
	30%B+70%FS
	40%B+60%FS
	50%B+50%FS
% of Bentonite(B) + % of Medium sand (MS)	10%B+90%MS
	20%B+80%MS
	30%B+70%MS
	40%B+60%MS
	50%B+50%MS

% of Bentonite(B) + % of Coarse sand (CS)	10%B+90%CS
	20%B+80%CS
	30%B+70%CS
	40%B+60%CS
	50%B+50%CS

Consolidation Test

Consolidation test was carried out to measure the swelling behaviour of sand-bentonite mix. Consolidation test was conducted following guide lines provided in (IS: 2720 Part XV; ASTM D 243), samples were prepared at compaction characteristics (MDD - OMC or MDD - 5%dry of OMC) and the sample was saturated prior to the consolidation test. The dimensions of ring were 60 mm internal diameter and 20 mm height and silicone grease was applied to the inner surface of ring to eliminate the friction between the ring and the soil sample. A porous stone and filter paper were placed both at the bottom and top of the soil specimen. The entire assembly was placed in the consolidation cell and positioned in the loading frame with a seating pressure of 5 kPa, water was added at top cap and allowed to swell until they reached equilibrium values of swelling. The pressure was increased day by day up to maximum and then the pressure was decreased day by day up to minimum. The corresponding vertical displacement with time was also measured. The apparatus used in this study has been shown in Figure 1.

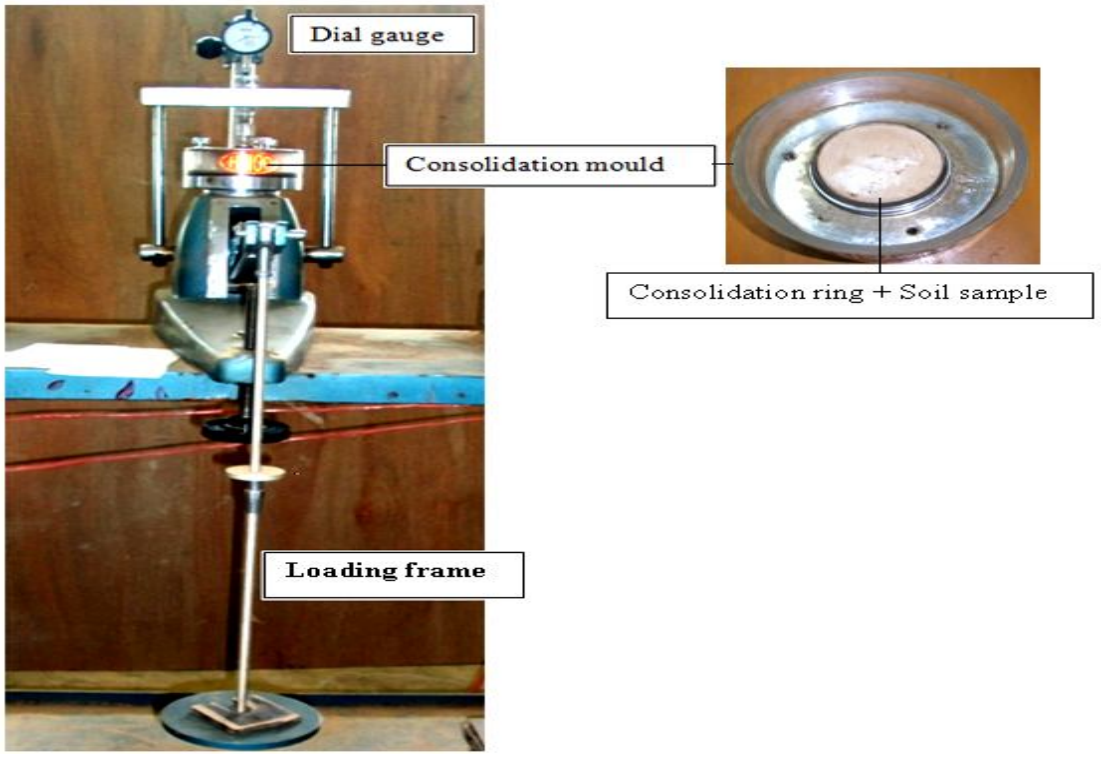

Figure 1: Oedometer Test

Results and discussion

In this study, the swelling behavior of bentonite sand mix was studied using consolidation test. The percentage swelling and swelling pressure of various sand-bentonite mixtures has been tabulated in Table 2.

Table 2: Results of swelling pressure on sand - bentonite mix:

Type of soil	Soil Mixture	Swell (mm)	% Swell of initial thickness	Swelling Pressure(Kg/cm^2)
Fine sand				
MDD - OMC				
	10%B+90%FS	0.004	0.03	0
	20%B+80%FS	0.256	1.72	0.45
	30%B+70%FS	0.996	6.73	1.5
	40%B+60%FS	1.83	12.12	1.65
	50%B+50%FS	2.918	19.41	1.85
MDD - 5% Dry of OMC				
	10%B+90%FS	0.034	0.22	0.09
	20%B+80%FS	0.764	5.09	0.68
	30%B+70%FS	1.006	6.75	1.2
	40%B+60%FS	2.674	17.95	2.7
	50%B+50%FS	3.558	23.94	3
Medium Sand				
MDD – OMC				
	10%B+90%MS	0	0	0

	20%B+80%MS	0.236	1.57	0.35
	30%B+70%MS	0.594	4.05	1
	40%B+60%MS	1.69	11.4	2.2
	50%B+50%MS	2.288	15.32	2.2
MDD - 5% Dry of OMC				
	10%B+90%MS	0.008	0.05	0
	20%B+80%MS	0.516	3.43	0.4
	30%B+70%MS	0.864	5.79	0.7
	40%B+60%MS	2.148	14.23	1.7
	50%B+50%MS	2.718	18	3
Coarse sand				
MDD - OMC				
	10%B+90%CS	0	0	0
	20%B+80%CS	0.102	0.68	0.2
	30%B+70%CS	0.924	6.18	0.5
	40%B+60%CS	1.696	11.28	1.4
	50%B+50%CS	2.306	15.24	2
MDD - 5% Dry of OMC				
	10%B+90%CS	0.018	0.12	0
	20%B+80%CS	0.358	2.41	0.33
	30%B+70%CS	1.106	7.47	0.71
	40%B+60%CS	2.002	13.53	1.51

	50%B+50%CS	4.014	27.07	3

The data in Table 2 shows that no swelling was observed for the 90% sand - 10% bentonite mixture for fine sand (FS), medium sand (MS) and coarse sand (CS). Since the swelling will take place only after the inter-void space of non-swelling particles are completely filled with swollen bentonite, the observation of non-swelling behaviour of mixtures indicated that the presence of 10% of bentonite is not sufficient enough to fill the void formed by the sand particles and to impact any swelling to the mixture. However, swelling behaviour was observed for 20% bentonite-80 % sand mixtures. A comparison among the various sand size (i.e. FS, MS and CS) of the mixture shows that the fine sand gives a higher value of swelling pressure and swelling compared to other two types of sand (i.e. MS and CS). This can be attributed to the existence of low void space in fine sand compared to other two sands.

Conclusion

In this study, the swelling behavior of bentonite sand mix was studied using consolidation test.

The results suggest that the fine sand gives a higher value of swelling pressure and swelling compared to other two types of sand (i.e. MS and CS). This can be attributed to the existence of low void space in fine sand compared to other two sands.

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