IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 13, Issue 4 Ver. III (Jul. - Aug. 2016), PP 91-96
www.iosrjournals.org

A Study on use of Brahmaputra River Sand as a Liner Material for Municipal Landfills

C. Doley[1], U.K. Das[2], P.K. Phukan[3], D. Dutta[4], P.M. Bora[5]
[1]*(Technical Officer, Civil Engineering Department, Tezpur University, India)*
[2]*(Associate Professor, Civil Engineering Department, Tezpur University, India)*
[3,4,5]*(Student, Civil Engineering Department, Tezpur University, India)*

Abstract: *Silty Sand is a pervious material in nature. Mixing silty sand with appropriate bentonite contents yields sand-bentonite mixtures having low hydraulic conductivity. A compacted mixture of bentonite with silty sand has been used to form a barrier for fluids in absence of impervious natural soil layer. This study focuses on the hydraulic conductivity behaviour of locally available silty sand and bentonite mixtures. Hydraulic conductivity tests were conducted to evaluate hydraulic conductivity of compacted sand-bentonite mixtures. Compaction tests are conducted to determine the optimum water content and maximum dry density of compacted sand-bentonite mixtures. Unconfined compressive strength of the sand-bentonite mixture is also measured to know the strength. The change in Atterberg limits of the soil-bentonite mixtures are also calculated and compared through the laboratory tests. Results of laboratory investigations are presented to show the influence of bentonite on compaction, Atterberg limits, unconfined compressive strength (UCS) and permeability of silty sand by increasing the bentonite content 5% by weight each time. The findings show significant improvement in the optimum moisture content and maximum dry density of sand-bentonite mixture with the increase in bentinite content. The study discusses the effect of bentonite content on strength and permeability, two important requirements of landfill liner material, of the sand-bentonite mixture.*
Keywords: *Bentonite, Landfill liner, Hydraulic conductivity, Silty sand, Unconfined compressive strength*

I. Introduction

Urbanization and industrialization are helping to grow several towns and cities in North Easternregion of the country. These towns and cities produce high quantities of municipal solid waste, often resulting in open dumping or municipal land filling. Leachate from open dumping yards and unscientific landfills cause environmental pollution especially ground water. Therefore barriers have to play a big role in arresting seepage of leachates from landfills. Different types of isolated liners have been widely used around the world, such as geosynthetic clay liners (GCL), high density polyethythene (HDPE), compacted clay liners (CCL), and soil-bentonite liners. However, under local conditions the construction cost of using these synthetic liner materials is exorbitant due to non-existence of local industry producing such materials. Further, these materials are subject to degradation affecting proper functionality as a liner material.

CCL are economical compared to others liners, only if the clay is locally available. Bentonite forms an integral part of landfill and waste depository liner due to its high swelling and lower hydraulic conductivity and contaminant adsorption capacity. However, high compressibility, high desiccation shrinkage, low shear strength and low compaction density are reasons of concern.

Soil-bentonite liner seems to be most economical solution for the geoenvironmental application in places which are covered mostly by sandy soils. Soil-bentonite liner is a way to prevent the ground water from being contaminated due to migration of the leachates by mixing soil such as sand with a low amount of bentonite and water as an insullation barrier. This kind of barrier has been presented in many research studies [Abeele (1986), Akgün et. al. (2006), Chapuis (1990), Mollins (1996)]. Typical cross section area of this landfill liner should be consisted of layers namely; a sand-bentonite layer, two filter layers, and protective layer [Chapuis (1990)], as shown in Fig.1 . The thickness of these layers is usually between 150 mm to 200 mm. The river silt of mighty river Brahmaputra, which runs through Assam in India and Bangladesh, is most abundantly available in its flood plains. In this study this locally available silty sand has been mixed with different proportions of bentonite to find out the optimum proportions of sand-bentonite mixture for landfill liners. To achieve this a low hydraulic conductivity is considered the key objective amongst other important parameters like compaction characteristics, Atterberg limit and shear strength of sand-bentonite mixture of this study.

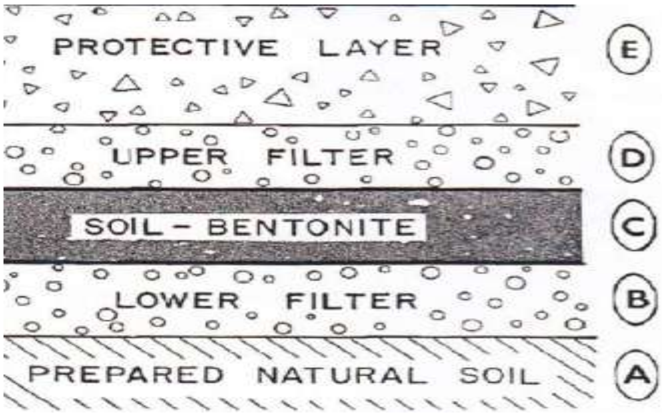


Fig.1. A typical cross section area of soil-bentonite landfill liner (Chapius 1990)

II. Materials and Methods

2.1 Materials

The silty sand used in this study were obtained from the bank of the Brahmaputra River near Tezpur, Assam. The river silty sand was sieved through 2.36 mm I.S sieve. The sand falls in the category of SP as per IS classification. The grain size distribution of the silty sand sample is shown in Fig.2. Physical properties of sand used are determined in laboratory and given in Table 1.

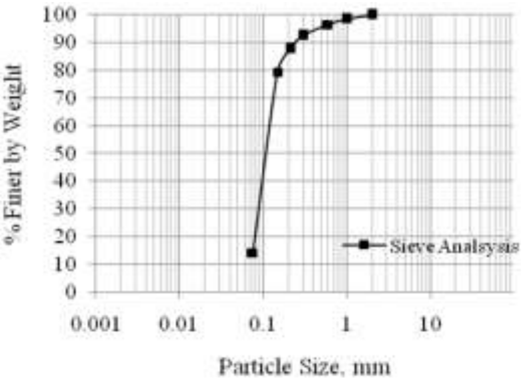


Fig. 2: Grain size distribution of the Brahmaputra silty sand sample

The bentonite used in this study was a powdered sodium bentonite. The main constituent, which is the determinant factor in the clay's properties, is the clay mineral montmorillonite. Bentonite is a clay generated frequently from the alteration of volcanic ash, consisting predominantly of smectite minerals, usually montmorillonite. Other smectite group minerals include hectorite, saponite, beidelite and nontronite. Smectites are clay minerals, i.e. they consist of individual crystallites the majority of which are < 2μm in largest dimension.Physical properties of bentonite used are determined in the laboratory and presented in Table 1.

2.2 Sample Preparation

Bentonite used was dried in air and then kept in temperature and moisture controlled environment. Sand used was oven dried. Different proportions of Bentonite i.e., 5%, 10%, 15%, 20%, 25% and 30% were added with the silty sand. Mixing was done by properly mixing in the dry sample before sprinkling the desired amount of water and mixing simultaneously. This method was adopted for uniformity of the mix. Tests conducted on samples without mixing in dry state showed irrelevant results because of the inhomogeneity of the mix. Bentonite used, swelled immediately after coming in contact with water and prevented uniform mixing. Compaction test samples were prepared at different water content (i.e. 6%, 10%, 14%, 20%, and 24%) for all bentonite proportions. Samples were kept in polythene bags to swell properly for a period of 7 days. Polythene bags avoided any change in moisture content but allowed mixture to swell. Compaction tests were performed on the samples after period of 7 days. Samples for Permeability test and UCS test were prepared at Maximum Dry Density and Optimum Moisture Content. Moreover, test Samples for permeability test, and UCS test were left for swelling in polythene bags for a period of 7 days.

Table 1: Physical properties of silty sand and bentonite used in the study

Properties	**Silty sand**	**Bentonite**
Liquid limit (%) W_L	18.27	147
Plastic limit (%) W_P	NP	40.78
Plasticity index I_P	NP	106
I .S classification	SM	CH
Specific gravity	2.67	2.33
UCS in kPa	0	-
Shrinkage limit (%)	-	11
Optimum moisture content (OMC) %	12.6	36
Maximum dry density (MDD) in g/cc	1.82	1.33

2.3 Experimental program

Tests on the silty sand and bentonite samples with different proportion of bentonite were performed in two stages.

In the first stage, geotechnical characteristics of the silty sand samples and bentonite samples were determined by conducting grain size analysis, specific gravity test, and consistency limits test.

In the second stage, geotechnical properties of silty sand and bentonite samples with different proportions of bentonite were determined. The silty sand was mixed with different percentages of bentonite (5, 10, 15, 20, 25 and 30%) by dry weight of total sample. Series of standard compaction test, specific gravity test, UCS test and the permeability test were conducted to determine geotechnical properties of sand and bentonite mixes.

III. Results and Discussion

3.1 Effect of bentonite on compaction characteristics of sand-bentonite mixtures

The compaction test were performed on the sand and bentonite mix with different proportions of bentonite

Table 2: OMC and MDD of sand and bentonite mixture

Material	Optimum Moisture Content (%)	Maximum Dry Density (g/cc)
95%S +5%B	16.4	1.745
90%S +10%B	15.8	1.753
85%S +15%B	15.1	1.765
80%S +20%B	14.3	1.779
75%S +25%B	13.0	1.789

in accordance with IS: 2720 (Part-7)-1980. The results for Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) of sand and bentonite samples presented in Table 2. Compaction curves for various sand and bentonite mix is shown in Fig 3.

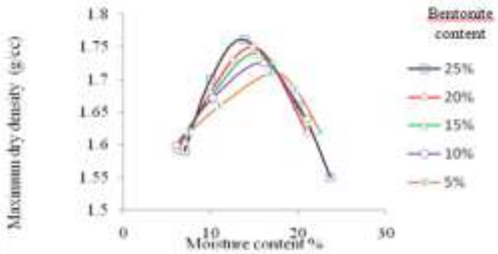
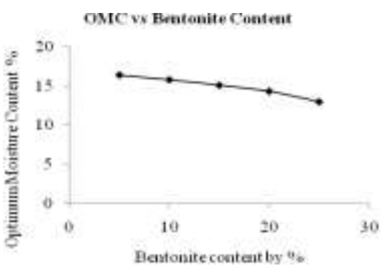


Fig. 3: Compaction curves for sand-bentonite mixture at different bentonite content

The variation of M.D.D with different percentage of bentonite is shown in Fig. 4 and variation of O.M.C with different percentage of bentonite is shown in Fig.5.



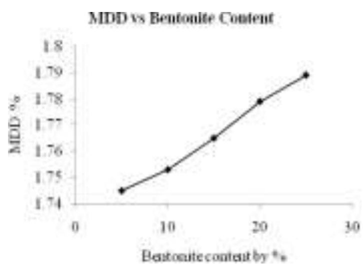


Fig. 4: Variation of OMC with bentonite content

Fig. 5: Variation of OMC with bentonite content

The curves from Fig.4 and Fig. 5 shows that with variation of Bentonite in sand samples, values of M.D.D increases from 1.745 g/cc at 5% bentonite mix to 1.789 g/cc at 25% bentonite mix and values of O.M.C decreases from 16.4% at 5% bentonite mix to 13% at 25% bentonite mix. Dry density increases with increased percentage of bentonite, because the voids with in the sand are occupied by the fine bentonite particles, which in result, increases the mass of soil solids for same volume. Due to this densification the chance for water to occupy the voids becomes less and water decrease with increase percentage of bentonite.

3.2 Effect of bentonite on Atterberg limits of sand-bentonite mixtures

Atterberg limit tests were conducted to study the effect of bentonite content on liquid limit, plastic limit, and plasticity index of the soil as per IS: 2720 (Part-5)-1985. Summary of liquid limit and plastic limit test results with different bentonite contents is given in Table 3.

An increasing trend of the consistency limits of the sand-bentonite mixture with increasing bentonite content is evident from Fig.6. As the percentage of bentonite increases from 5 to 30%, the liquid limit calculated by the casagrandes method increases from 21.21 to 33.51%. Plastic limit (PL) and plasticity index (PI) also increase with respect to bentonite content. The plastic limits for the mixture could not be calculated as the mixture was non-plastic but it could be calculated from 20% bentonite since plasticity increased with bentonite quantity. Plastic limit (PL) increases from 24.63 to 28.3% for bentonite 20 to 30% respectively. Similarly plasticity index (PI) also increases from 2.92 to 5.21 for 20 to 30% bentonite respectively.

Table 3: Variation of Atterberg limit with different percentage of bentonite

Material	W_L	W_P	I_P
95%S +5%B	21.21	NP	-
90%S +10%B	23.82	NP	-
85%S +15%B	25.63	NP	-
80%S +20%B	27.55	24.63	2.92
75%S +25%B	30.17	26.13	4.04
70%S +30%B	33.51	28.3	5.21

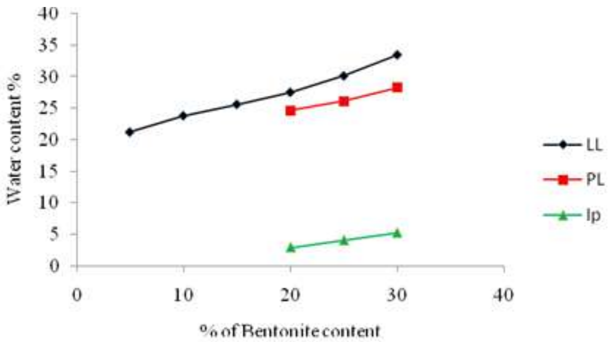


Fig. 6: Variation of Atterberg Limit with different % of bentonite

It is well known that the liquid limit and plastic limit of a soil are primarily controlled by its clay content [Seed et al.(1959)]. Therefore, the increases in liquid limit and plastic limit were expected as clay content was increased due to the addition of bentonite.

3.3 Effect of bentonite on Unconfined Compressive Strength (UCS) of sand-bentonite mixtures

Unconfined compressive strength (UCS) test were performed on cylindrical specimens 38mm in diameter and length of 76mm in accordance with IS: 2720 (Part-10)-1991. The bentonite quantity in the samples were increased by 5% by weight each time and the samples were tested for strength. The test results are shown in Fig.6. From The unconfined compressive strength for sand-bentonite mixtures ontained from Fig.7 are shown in Table 4.

The curve in Fig. 7 shows that with varriation of bentonite in sand samples, the UCS values increases from 7.6 kPa at 5% bentonite mix to 76.73 kPa at 25% bentonite Mix. The increase in strength can be best explained by the change of soil structure due to the presence of bentonite. This explanation is supported by theory on factors influencing shear strength of compacted clays developed by Lambe (1960). When bentonite is added, the soil structure becomes flocculated due to reduction in interparticler repulsion. Lambe (1960) reported that greater repulsion results in lower shear strength. Therefore, the soil has higher shear strength when bentonite is added because the repulsion is reduced. Another factor that could cause increase in shear strength is particle orientation. Lambe (1960) summarized that for any given void ratio and given average particle spacing, the more nearly parallel are, the particles the weaker is the soil. Because increased flocculation means a more random particle orientation, soil shear strength will become greater when bentonite is added as soil became more flocculated.

Table 4: UCS with different percent of bentonite

Material	UCS (kPa)
95%S +5%B	7.6
90%S +10%B	22.9
85%S +15%B	39.23
80%S +20%B	60.44
75%S +25%B	76.73

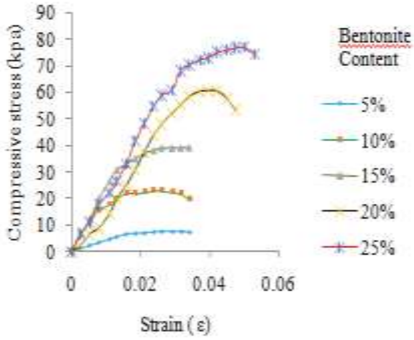


Fig. 7: Stress vs Strain with different % of bentonite content

3.3 Effect of bentonite on hydraulic conductivity of sand-bentonite mixtures

The permeability test were performed on the sand and bentonite mix with different proportions of bentonite in accordance with IS: 2720 (Part-17)-1986. The test results are shown in Table 4. A plot of Coefficient of permeability vs. Bentonit content in Fig.8 reveals that the hydraulic conductivity of sand-bentonite mixtures decreases with increasing bentonite content. Hydraulic conductivity decreased from 1.10 $\times 10^{-4}$cm/s for the soil without bentonite to 4.0 ×10-8cm/s for the soil with 30% bentonite. The common regulatory requirement for compacted soil liners states that the hydraulic conductivity should be less than 1×10^{-7} cm/s. For bentonite additions of more than 30%, the hydraulic conductivity is around 1×10^{-8} cm/s. From the plot it is seen that the coefficient of hydraulic conductivity decreases abruptly upto addition of 20% bentonite. Coefficient of permeability, k increases with increase in void ratio. At very low bentonite contents void ratio is high. The very low bentonite content leads to an uneven distribution of bentonite within the sand matrix and this resulted in preferential flow-paths.

Table 4: Coefficient of permeability with different percentage of bentonite

Material	Coefficient of Permeability, (k) cm/sec
100%S +0%B	1.10E-04
95%S +5%B	1.85E-05
90%S +10%B	2.94E-06
85%S +15%B	7.00E-07
80%S +20%B	1.60E-07
75%S +25%B	7.00E-08
70%S +30%B	4.00E-08

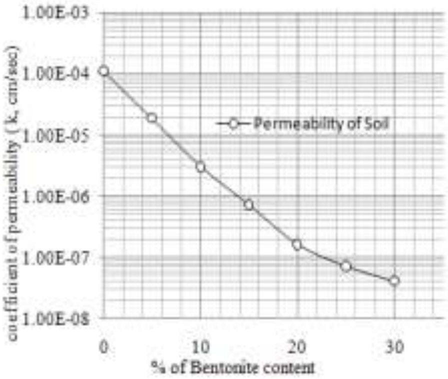


Fig.8 Change in coeff. of permeability with bentonite content

IV. Conclusion

From the study on the effect of bentonite on locally available soil for different proportion of sand-bentonite it can be conclude that when the bentonite content varies from 5 to 25%, the maximum dry unit weight increases from 1.745 to 1.789 g/cc and the corresponding optimum water content decreases from 16.4 to 13.0 %. Liquid limit, plastic limit and plasticity index also increases with the increasing bentonite content. Similarly with the increase in the bentonite content, unconfined compressive strength also increases from 7.6 to 76.78 kPa for 5% to 25% bentonite respectively.Result indicate that hydraulic conductivity decreased from 1.10 $\times10^{-4}$cm/s for the soil without bentonite to 4.0×10^{-8}cm/s for the soil with 30% bentonite. When bentonite is added to silty sand, due to its very small particle size it occupies the pore space present between the individual sand grains. Once the bentonite comes in contact with water, it starts to swell and fill these void spaces resulting in a decrease in the hydraulic conductivity of the mixture.

The study, in conclusion, shows high potential of Brahmaputra river sand mixed with 20-30% bentonite (by weight of dry soil) for use as a liner material in municipal landfills.

References

[1] Abeele, W.V.,The influence of bentonite on the permeability of sandy silts. *Nuclear AndChemical Waste Management*, 6(1), 1986, 81-88.

[2] Akgün, H., Koçkar, M. K., and Aktürk, Ö., Evaluation of a compacted bentonite/sand sealfor underground waste repository isolation. *Environmental Geology*, 50(3), 2006, 331-337.

[3] Chapuis, R.P., Sand-bentonite liners: predicting permeability from laboratory tests. *Canadian Geotechnical Journal*, 27(1), 1990, 47-57.

[4] IS: 2720 (part-3/sec-I)-1980, Method of test for soils - Determination of Specific gravity-fine grained soil.

[5] IS: 2720 (part-4) 1985, Method of test for soils - Grain size analysis.

[6] IS: 2720 (part-5) 1985, Method of test for soils – Determination of liquid and plastic limit.

[7] IS: 2720 (Part 10) 1991, Method of test for soil - Determination of unconfined compressive strength.

[8] IS: 2720 (Part 17)-1986, Method of test for soil – Laboratory determination of permeability.

[9] Kaya, A., Kayalar, A.S. and Oren, A.H. , Hydraulic conductivity of zeolite - bentonite mixtures in comparison with sand – bentonite mixtures, *Canadian Geotechnical journal,* 48, 2011, 1343-1353.

[10] Lambe, T. W., Compacted clay: structure: *Trans. Am. Soc. Civil Engineers*, 125, Part 1, 1960,681-705.

[11] Mollins LH, Predicting the properties of bentonite-sand mixtures. *Clay Minerals* 31(2), 1996, 243–252

[12] Seed, H. B. and Chan, C. K. , Structure and strength characteristics of compacted clays: *J. Soil Mechanics Found Div., Am. Soc. Civil Engineers* 85, SM-5,1959, 87- 128.

[13] Sivapullaiah, P.V., Sridharan, A., and Stalin, V.K., Hydraulic conductivity of bentonitesand mixtures. *Canadian Geotechnical Journal*, 37(2), 2000, 406-413.