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Performance of admixture soil as a bottom liner of landfill

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Abstract: A bottom liner of landfill is intended to be a low permeable barrier, which is laid down under engineered landfill sites. Until it deteriorates, the liner retards migration of leachate, and its toxic constituents, into underlying aquifers or nearby rivers, causing spoil of the local water. To improve the quality of local clayey soil (from kuet campus at a depth of 5-7feet below the ground level) as a bottom liner of landfill an admixture (bentonite clay) has been mixed with that soil at different proportions. The criteria as clay liner such as (coefficient of permeability) k≤ $1x10^{-7}$cm/sec, (plasticity index) pi>7%, 30% fines of which 15% is clay and (water content) w%> plastic limit has been checked with the mix of bentonite respectively 0%, 7% and 10% (daniel & coerner,1995). All criteria were not met when checked without mixing any amount of bentonite with sample specimen. After that, 7% bentonite was mixed with the soil and slight improvement was found in the properties of soil. Finally increasing the amount of bentonite as 10% all the criteria were met. Coefficient of permeability was found as $0.54x10^{-7}$cm/s, plasticity index was 16.80%, percentage of fines was greater than 30% and optimum moisture content was greater than plastic limit.

Keywords: *Landfill, bentonite as admixture ,bottom liner and safe disposal of solid waste*

1. Introduction:

The solid waste management facility regulations require that a groundwater protection system (commonly referred to as a liner system) be installed at all new or expanding landfills. The purpose of a liner system is to prevent leachate from reaching groundwater by collecting leachate for treatment and disposal. By preventing the movement of leachate into groundwater, the bottom liner serves to protect groundwater and surface water from pollution. A bottom liner of landfill is intended to be a low permeable barrier, which is laid down under engineered landfill sites. Until it deteriorates, the liner retards migration of leachate, and its toxic constituents, into underlying aquifers or nearby rivers, causing spoil of the local water.

For hazardous waste landfills, double liners are required. The double liners include a top liner designed to prevent the migration of hazardous constituents into the liner during the active life and post-closure period and bottom liner consisting of one or more layers of clay having conductivity of no more than $1x10^{-7}$ cm/s.

The low hydraulic conductivity of clay minerals makes them potential materials to use as liner landfill for environmental protection. Soils classified as inorganic clay with high plasticity is considered are the suitable material for landfill (Oweis & Khera 1998). If naturally available clay or clayey soil is not suitable for bottom liner, kaolinite or commercially available high swelling clay (Bentonite) can be mixed with local soils or sand. As Bentonite is naturally occurring, locally available, cost-effective and has the chemical composition of altering physical properties of soils an attempt to use it as an admixture has been carried out.

In this study soil samples were collected from KUET campus from 5 to 7 feet depth. A soil to be used as bottom liner is to fulfill some major criteria such as hydraulic conductivity less than $1x10^{-7}$cm/sec, plasticity index greater than 7%, at least 30% fines of which 15% clay and water content should have to be greater than plastic limit. The soil sample was tested against these criteria and found not suitable for using as bottom liner unless admixture used. For that reason Bentonite was mixed with the soil sample at different proportions and found out the optimum percentage of Bentonite mixture.

2. Methodology:

This research work has been conducted upon simple methodology of determining some basic physical parameters of soil which are considered as criteria of being liner of landfill. First, a soil sampling has been made collecting local soil from KUET campus from 5-7 feet depth below the ground level. Then specific gravity, plasticity index, hydraulic conductivity, percentage of fines and remoulding water content were checked for this soil sample. Then mixing 7% bentonite, criteria were checked again and analysed. Upon the results found by 7% mixing, these criteria were rechecked at an increased amount of mixing proportion of bentonite clay as 10%.Then results were analysed and interpreted, the suitable amount of bentonite when requirements met, clay as admixture, has been considered as the optimum mixing proportion.

2.1 Specific gravity test:
The specific gravity of a soil is the ratio of the weight in air of a given volume of soil particles to the weight in air of an equal volume of water at a temperature of 4^0c. The specific gravity of a soil is often used in relating of soil to its volume.

2.2 Atterberg limits test:
The liquid limit, plastic limit and shrinkage limit of the soil samples were determined based on Atterberg limits test following the testing standard D4318.

2.3 Particle size analysis by hydrometer method:
Hydrometer analysis method is applicable for soil particle smaller than 0.075mm. The percentage of sand, silt and clay size can be obtained from this test.

2.4 Determination of remolded water content:
The maximum dry density and optimum moisture content of the soil were determined in the laboratory by standard proctor test following the testing standard ASTM D558.

2.5 Permeability Test:
The hydraulic conductivity of clay samples were measured using rigid wall perimeter under falling head condition.

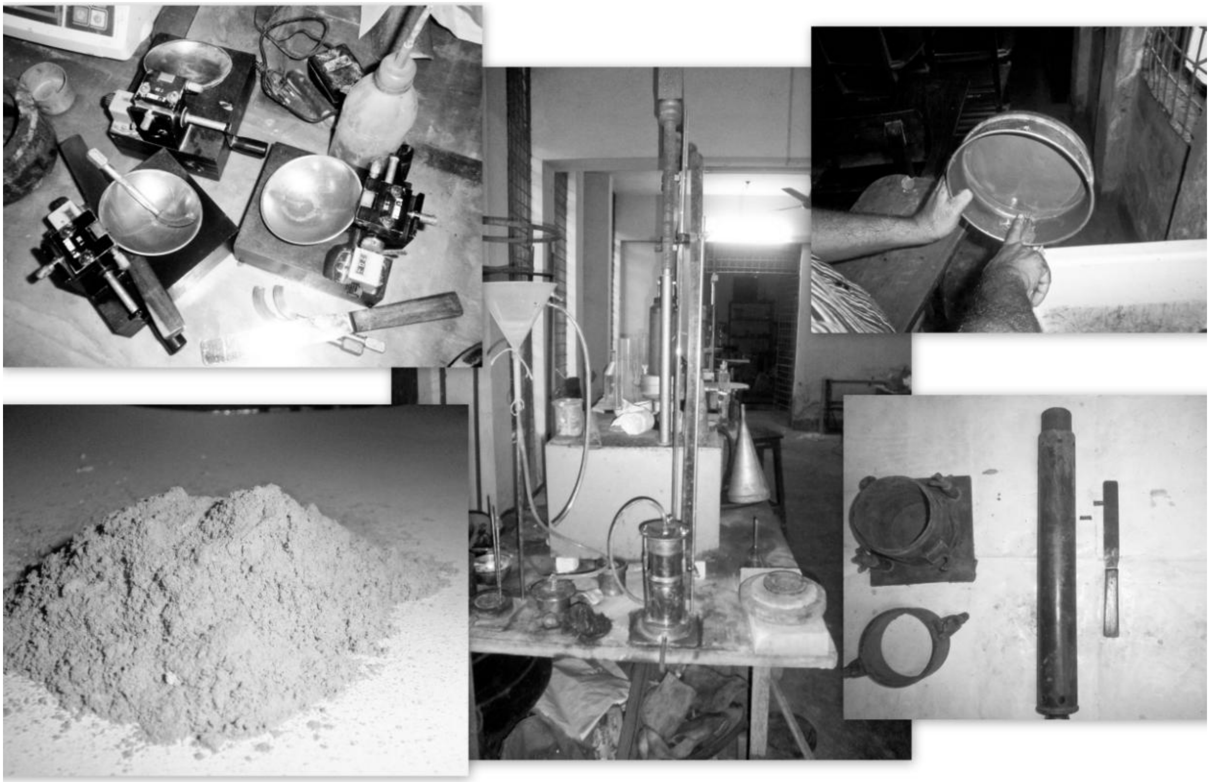

Figure 1: practical photographs of laboratory setup

3. Illustrations:
Atterberg limits test:
The liquid limit, plastic limit and shrinkage limit of the soil samples were determined based on Atterberg limits test following the testing standard D4318.

A plot was made of water content against number of blows. This plot is known as “flow curve”. From this curve liquid limit was found 33.52%.

Table 1: liquid limit determination

Can no	c1	c2	c3	c4
Mass of wet soil+can	44	58.5	55	45
Mass of dry soil+can	38.4	49.1	46.8	39.5
Mass of can	22.1	22.5	22.3	22.3
Mass of dry soil	16.3	26.6	24.5	17.2
Mass of moisture	5.6	9.4	8.2	5.5
w%	34.36	35.34	33.47	31.98
No of blows	19	16	26	33

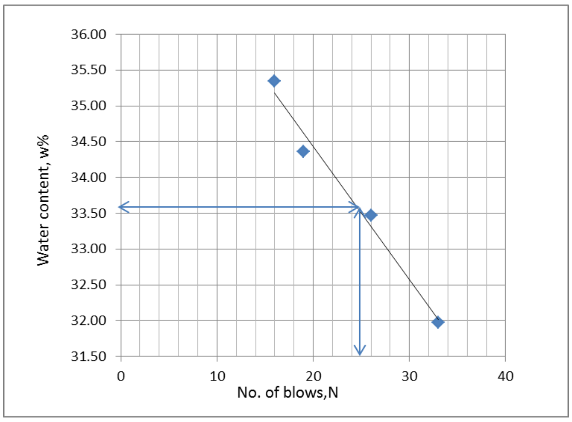

Figure 2: flow curve

Table 2: plastic limit determination

can id	c5	c6	c7	Average
wet soil+can	27.7	28.9	24.3	
dry soil+can	26.5	27.4	24	
mass of can	22.3	22.3	22.7	
dry soil	4.2	5.1	1.3	
mass of moisture	1.2	1.5	0.3	
plastic limit	28.57	29.41	23.08	27.02

Plasticity index, PI= 6.50%

With the same procedure mixing 7% and 10% bentonite clay with the soil plasticity index were determined 10.99% and 16.80% respectively.

Particle size analysis of bottom liner through hydrometer method

Table 3: particle size analysis

Sieve No.	Sieve Opening	Weight Retained	Cumulative Weight Reatined		% Finer
	(mm.)	(gm.)	(gm.)	%	%
4	4.75	0	0	0	100
8	2.36	0	0	0	100
20	0.85	0	0	0	100
40	0.425	5.6	5.6	5.6	94.4
60	0.25	14.2	19.8	19.8	80.2
150	0.104	13.1	32.9	32.9	67.1
200	0.075	4	36.9	36.9	63.1
PAN					
Sample Amount (Gm.)		100			
Dry Mass (Gm.)	Zero Corrction (C_o)	Specific Gravity (G_s)	A	Meniscus (C_m)	Dispersing Agent
50	6	2.7	0.99	1	$NaPO_3$

Elapsed Time	Temp	Actual Hyg. Reading	Tep. Corr. C	Corr. Hyg. Reading	Act. % Finer	Adj. % Finer	Hyg. Read With Meniscus Corr.	L	L/T	K	Particle Size (D)
(min.)	(^{O}C)	R_a	Table 6.3	R_c	F_b		R				mm.
0											
2	24	41	1	36	71.28	44.97768	42	9.412	4.706	0.0128	0.0278
4	24	34	1	29	57.42	36.23202	35	10.56	2.64	0.0128	0.0208
8	24	30	1	25	49.5	31.2345	31	11.216	1.402	0.0128	0.0152
15	24	26	1	21	41.58	26.23698	27	11.872	0.7915	0.0128	0.0114
30	24	22	1	17	33.66	21.23946	23	12.528	0.4176	0.0128	0.0083
60	24	19	1	14	27.72	17.49132	20	13.02	0.217	0.0128	0.006
120	24	17	1	12	23.76	14.99256	18	13.348	0.1112	0.0128	0.0043
180	24	15	1	10	19.8	12.4938	16	13.676	0.076	0.0128	0.0035
300	24	14	1	9	17.82	11.24442	15	13.84	0.0461	0.0128	0.0027
480	24	12	1	7	13.86	8.74566	13	14.168	0.0295	0.0128	0.0022
1440	24	11	1	6	11.88	7.49628	12	14.332	0.01	0.0128	0.0013

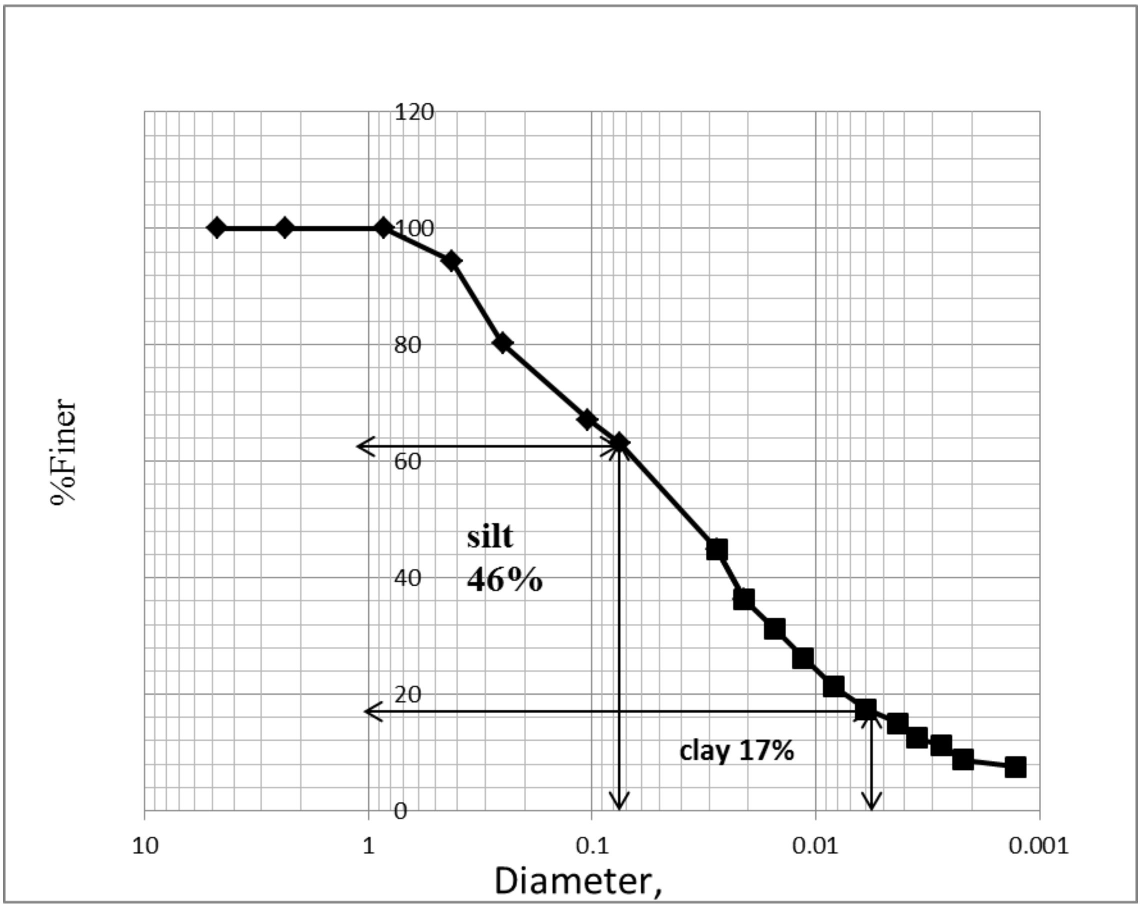

Figure 3: particle size analysis curve by hydrometer method

Thus, percentage of fines for 7% and 10% mixing of bentonite clay of that soil were determined.

Determination of compaction properties

The maximum dry density and optimum moisture content of the soil were determined in the laboratory by standard proctor test following the testing standard ASTM D558.

Table 4: Density determination of the sample without bentonite

Assume w%	8	11	14	17	20	23
W%	10.86	14.33	17.49	23.06	23.01	29.94
Wt. of soil+mold	3163	3241	3352	3412	3373	3330
Wt.of mold	1743	1743	1743	1743	1743	1743
Wt. of soil in mold	1420	1498	1609	1669	1630	1587
Wet density,KN/m3	13.93	14.70	15.78	16.37	15.99	15.57
Dry density,KN/m3	12.57	12.85	13.43	13.31	13.00	11.98

Based on the graph, the optimum moisture content was 19% and maximum dry density was 13.30 KN/m^3. Remoulding water content of that soil with the mix of 7% and 10% bentonite clay were determined also.

Permeability test

The hydraulic conductivity of clay samples were measured using rigid wall perimeter under falling head condition.

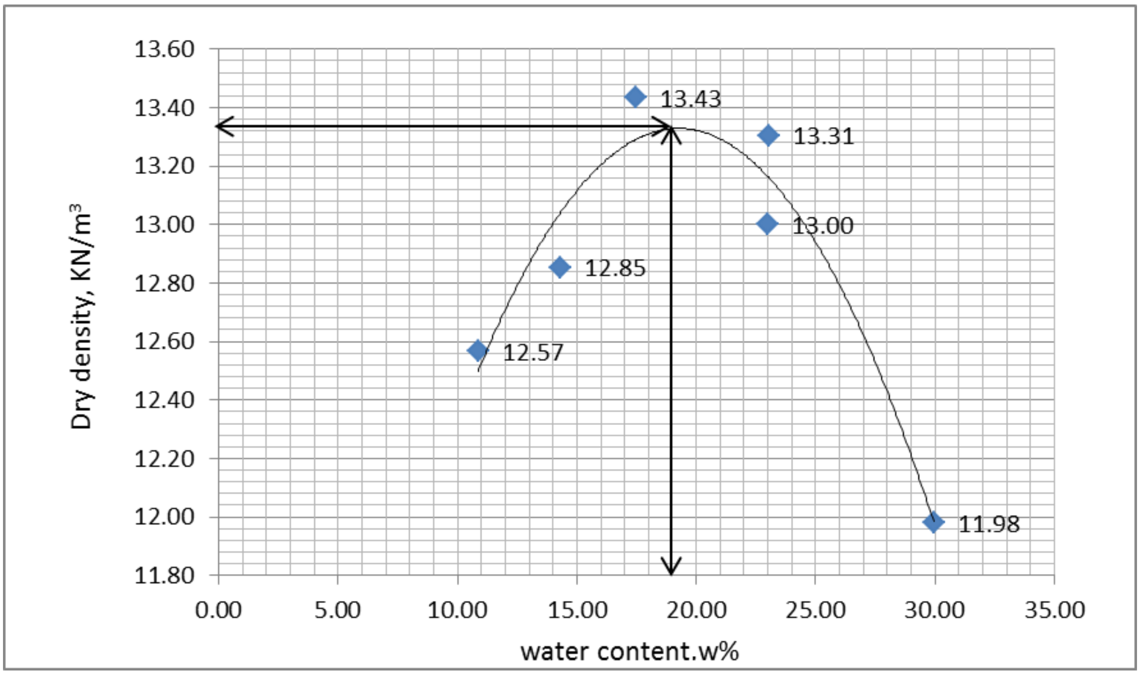

Figure 4: water content vs. dry density relationship

Table 6: Hydraulic conductivity of the sample without bentonite at 19% water content

Obs. no	Length of soil sample, L (cm)	Cross sectional area of soil specimen, A (cm^2)	Cross sectional area of stand pipe, a (cm^2)	Initial head,h1(cm)	Final head,h2(cm)	Time,t(min)	Hydraulic conductivity,K (cm/s) $x10^{-7}$
1	8.8	30.778	0.79	100	99	120	2.93955
2	8.8	30.778	0.79	100	95	440	4.09156
3	8.8	30.778	0.79	100	90	1380	2.67966
4	8.8	30.778	0.79	100	87	960	5.09146
						Avg.= 3.70 x 10^{-7}	

With this same procedure coefficient of permeability of the soil sample were determind for mixing 7% and 10% bentonite clay $2.07x10^{-7}$cm/sec and $0.54x10^{-7}$cm/sec respectively.

The performance bottom liner depends on the natural characteristics of soil and admixture used. The plasticity index with 0%, 7% and 10% bentonite of soil sample were 6.50%, 10.99% and 16.80% respectively. The plasticity of a soil refers to its capability to behave as a plastic material. And the plasticity index must be greater than 7% (Daniel 1993; Benson et. Al. 1994)

The optimum moisture content and maximum dry density have been obtained by standard compaction test. Standard compaction test keeps the water content at a reasonable value and doesn't increase the value of dry density too much like modified compaction test. The water content and dry density with 0%, 7% and 10% bentonite were found (19%, 13.30KN/m^3) and (18.5%, 15.19 KN/m^3) and(19%, 15.30KN/m^3). At 0% and 7% bentonite mixing the water content was less than plastic limit but by mixing 10% bentonite with soil sample it was found greater than plastic limit.

The percentage of fines was satisfactory which was greater than 30% in every sampling. The percentage of clay was greater than 15% also.

The most important and vital factor of landfill is permeability which denotes the rate of percolation of leachate and other harmful substances. As why, this always should have to be within safe limit. When no admixture was used it was found almost greater than three times of safe limit which was $3.70x10^{-7}$cm/s. After using 7% bentonite slight improvement was observed and that was $2.07x10^{-7}$cm/s. Finally increasing the amount of bentonite as 10% the coefficient of permeability was found $0.54x10^{-7}$cm/s $< 1x10^{-7}$cm/s.

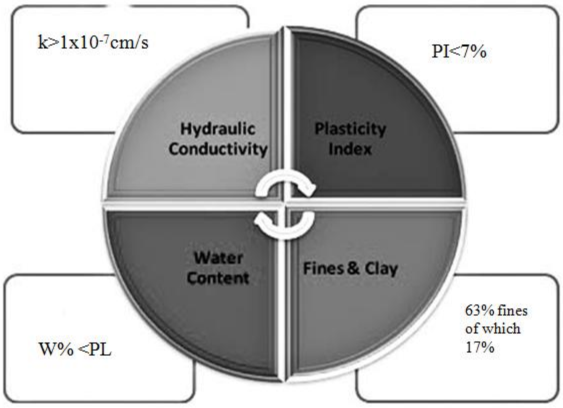

Figure 5: engineering properties of soil as bottom liner when no bentonite used

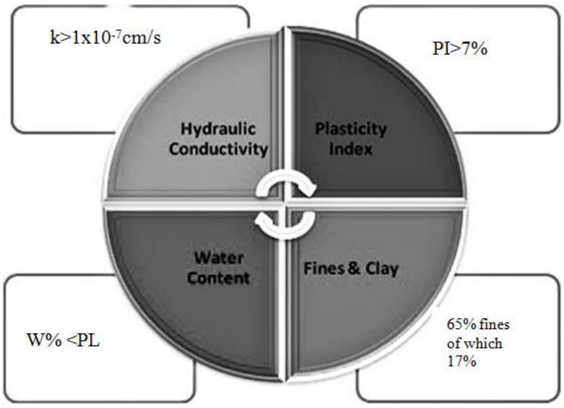

Figure 6: engineering properties of soil as bottom liner when 7% bentonite used

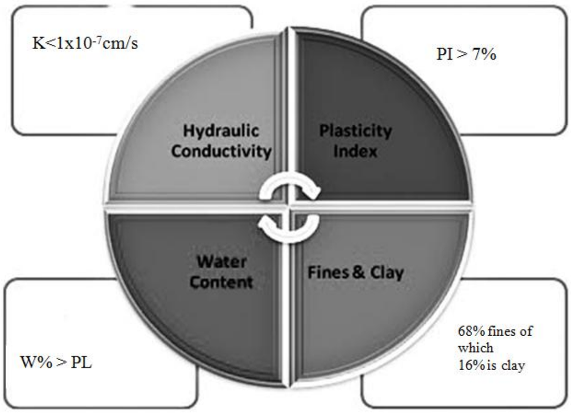

Figure 7: engineering properties of soil as bottom liner when 10% bentonite used

Above three figures show the change of hydraulic conductivity, plasticity index, % of fines and remolding water content with respect of variation of mixing proportion of bentonite. It was found that when no bentonite was used as admixture all three criteria did not satisfy except percentage of fines. After mixing 7% bentonite only plasticity index had met the condition, additionally with the percentage of fines. Finally, increasing the amount of mixing proportion as 10% of bentonite results were found pretty appreciable. All four criteria were met. So, 10% bentonite can be an optimum proportion while bottom liner designing.

4. Conclusions:

First sampling did not satisfy except percentage of fines. That means the soil sample has fines more than 30% of which at least 15% clay. When second sampling was made with mixing 7% bentonite plasticity index met the requiring condition but the water content had been less than plastic limit. In third sampling all four requirements were satisfied and hence it can be considered that 10% use of bentonite is the optimum for that kind of soil as a bottom liner.

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