International Journal of Scientific Engineering and Research (IJSER)
ISSN (Online): 2347-3878
Index Copernicus Value (2015): 56.67 | Impact Factor (2017): 5.156

Use of Sukhna's Silt as a Liner Material in Landfill

Srishti Nagpal, Mukesh Kwatra

B.E in Civil Engineering, PEC University of Technology, Chandigarh, India

Abstract: ***Sukhna lake of Chandigarh is roughly kidney shaped, located at 32° 42' N Lat. and 76° 54' E Long. With its concavity facing the Shivalik Hills its northern boundary adjoining the Shivalik Hills is natural and irregular and SW embankment, artificially built out of hewed stones, has a rock fill earth dam 12.8 m high. The lake is 1.52 km long and 1.49 km wide with initial storage capacity of 1,074 ha-m of water. The catchment area of the choes feeding the lake have rugged terrain, steep slopes, plenty of gulleys, very deep-water table and the soils are predominantly alluvial sandy embedded with layers of clay which are highly susceptible to soil erosion by water run-off action. The impact of rain drops, quick flow of run-off and exposed soil coupled with hill denudation due to deforestation and animal grazing, are ideal conditions in the area for soil erosion. The water flowing into the lake is heavily loaded with silt. This silt deposited year after year in the lake bed reduces the water storage capacity, depth; water spread area and submergence area at lake level. [Source: Bansal and Grewal (1986, 1990) and CSWCR & TI (1993)]. From the previous researches it can be concluded that, 1. The average annual silt deposits are variable due to ineffectiveness of the measures taken as well as periodic differences in weather conditions. 2. All this points to the fact that anti erosion and anti-siltation measures in the catchment area and Sukhna Lake respectively need to be taken simultaneously and on a continual basis. The aim of this paper is to explore and test the suitability of this silt mixture (with bentonite and flyash) as a liner material used in landfills.***

Keywords: Silt/Flyash/Bentonite/ Liner material in landfill/ Geotechnical / Sukhna lake

1. Literature Review

The problem of siltation is not new to Sukhna Lake. Some of the measures taken to address the issue in the past include:

- During 1972-1973 Kansal Choe was diverted into Saketri Choe which joined the lake at its eastern end. But because of steep slopes of the diversion channel and due to reduction in the length, the inflow of silt into the lake got accelerated, especially in the area near Spillway Regulator.
- Silt was removed from the Spillway Regulator area during dry season (April-June) every year creating a basin which receives silt during next monsoons.
- For the proper maintenance of the water shed area of the lake, the Punjab Government before state Reorganization in 1966 acquired an area of 6,172 acres which under. Punjab Reorganization Act 1966 was redistributed as 2,155.72 acres in Punjab and 4,016.28 acres in Haryana. However, the control of the whole area was later vested with U.T. Chandigarh for undertaking composite soil conservation measures.
- It was concluded that critical sources contributing sediment load in Sukhna Lake were stream bank erosion, steep sloping hills and steep bare hills which were severely gullied and suffered from landslips.
- During 6th Plan (1977-1978 to 1982-1983) the Forest Department of U.T. Chandigarh executed Central Government sponsored scheme of soil conservation at a cost of Rs. 73.41 lacs.
- Scientists of Central Soil Water Conservation Research and Training Institute (CSWCR and TI) identified a village Sukhomajri located at the head of Kansal Choe for model water shed management. Under a centrally Sponsored Scheme for Sediment Control of Sukhna Lake in 1978 villagers were persuaded to do away with their goats (which grazed freely over the hills of catchment area) and instead advised to go in for agriculture, several small dams were constructed for storing run off water to be made available for agriculture round the year. Soil conservation measures such as contour bunding and tree plantation were adopted which helped in reducing the silt in Sukhna from 141 tons/ha in 1974 to 14 tons/ha after 1979
- In 1986, the annual auctions for seasonal lease of fodder grass from the forest areas adjoining villages on the periphery of the lake catchment were stopped by the Haryana Forest Department and the lease was given to Hill Management Societies of these villages.
- In 1988, Ministry of Environment and Forest, Government of India, recognized 228.66 ha of Sukhna Lake as one of the National Wetlands that needed priority for conservation. The measures taken to conserve the Sukhna Wetland included plantation of locally suitable varieties of trees numbering 160,000 during 1989-1990, aerial spray of seeds and fertilizes in the entire catchment area and provided two decantation tanks near the Regulator to arrest silt (CSWCR and TI, 1993).

Conclusions derived from the previous studies

- From foregoing account, it is amply clear that the average annual silt deposits are variable due to ineffectiveness of the measures taken as well as periodic differences in weather conditions.
- All this points to the fact that anti erosion and anti-siltation measures in the catchment area and Sukhna Lake respectively need to be taken simultaneously and on a continual basis.

2. Introduction

Rapid technological advances and ever-increasing consumer needs has led to production of hazardous wastes. Today, our society faces two fundamental issues namely, waste management and pollution risk control. One of the solutions to the problem of ever increasing waste is to dump it in a specific location sealed using insulated barriers. Many different barrier materials exist, for example plastic membrane, sand bentonite compacted

Licensed Under Creative Commons Attribution CC BY

layers, cement stabilised soils. Permeability of the membrane is one of the most important properties for the design of barrier material in a landfill. Permeability of barrier materials has been studied by many authors for different type of soil, compacted clays, mine tailings, and sand bentonite mixtures. The efficiency of these insulated barriers depends largely on their permeability along with their abilities of contaminant retention. In this paper, we aim to study the potential use of two waste materials (fly ash and silt) in the design of barrier material for landfill.

For compacted soil mixtures to be efficient as insulation barriers, they should fulfil following specifications:

Table 1: Comparison of geotechnical properties between sukhna's silt and liner material in landfill

Property	Required range	Sukhna's silt
Plasticity Index	10-30%	7.467
Maximum particle size	25-30 microns	27 microns
Permeability	10^{-7}cm/s	10^{-6}cm/s
Percentage fines	>20 %	68%

The investigation study was carried out on 12 mixtures with varying compositions of sukhna's silt (varying between 55% and 100%), flyash (varying between 10 % and 30%) and bentonite (varying between 5% and 15%) additions. The adequate bentonite addition to the mixtures, which satisfies the required conditions of the permeability, was obtained using consolidation test. This was followed by finding the retention capacity of the mixture to adsorb several chemicals which is performed using the batch absorption test using Atomic Absorption Spectrophotometer.

3. Materials Used

Silt

During the last hundred years or so, deforestation and wind-water borne soil erosion has steadily increased and is becoming a major environmental problem world over. The man-made Sukhna Lake situated in Chandigarh, India brought into existence through blocking of the water flow in Sukhna choe originating from the hills by rising of stone-cum-earthen embankments, is experiencing siltation over the years right from its completion in 1958.

The problem of Sukhna's siltation was first addressed in 1971 and since then several measures have been taken to control the problem of siltation but to no success. From the previous researches it can be concluded that:

1. The average annual silt deposits are variable due to ineffectiveness of the measures taken as well as periodic differences in weather conditions.
2. All this points to the fact that anti erosion and anti-siltation measures in the catchment area and Sukhna Lake respectively need to be taken simultaneously and on a continual basis.

Till now the sediments taken out from the lake were deposited on the ground adjoining the road connecting Sukhna Lake and Saketri. Most of this deposited sediment has so far been used in design of highway pavement and road construction.

The objective of this research is to check the suitability of this silt for its use in design of barrier layer/liner in a landfill.

In search of an adequate mixture, an investigation study is carried out on several mixtures with different percentages of sukhna's silt (varying between 55% to 100%), flyash (varying between 10 % to 30%) and bentonite (varying between 5% to 15%) additions. The adequate bentonite addition to the mixtures, which satisfies the required conditions on the permeability, is obtained using oedometer test. Then after, the retention capacity of the mixture to adsorb several chemicals which is performed using the batch absorption test using Atomic Absorption Spectrophotometer.

Bentonite

The different types of bentonite are each named after the respective dominant element, such as potassium (K), sodium (Na), calcium (Ca), and aluminium (Al). Bentonite is usually formed after weathering of volcanic ash under the presence of water. The property of swelling on contact with water makes sodium bentonite useful as a sealant, since it provides a self-sealing, low-permeability barrier. It is used to line the base of landfills to prevent migration of leachate and for quarantining metal pollutants of groundwater. Similar uses include making slurry walls, waterproofing of below-grade walls, and forming other impermeable barriers, e.g., to seal off the annulus of a water well, to plug old wells. It is also used to form a barrier around newly planted trees to constrain root growth to prevent damage to nearby pipes, footpaths and other infrastructure.

Farmers use bentonite to seal retention ponds. In India, bentonite clay is found in the Saurashtra area covering parts of Gujarat and Maharashtra state.

Fly-Ash

Fly ash is one of the coal combustion products, composed of the fine particles that are driven out of the boiler with the flue gases. Ash that falls in the bottom of the boiler is called bottom ash. In modern coal-fired power plants, fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys. Together with bottom ash removed from the bottom of the boiler, it is known as coal ash. Fly ash includes substantial amounts of silicon dioxide (SiO_2) (both amorphous and crystalline), aluminium oxide (Al_2O_3) and calcium oxide (CaO), the main mineral compounds in coal-bearing rock strata.

Fly ash when dispersed in the atmosphere becomes a cause of various health and environmental concerns. The environmental benefit to recycling fly ash includes reducing the demand for virgin materials that would need quarrying and cheap substitution for materials such as Portland cement. Over the years fly ash found its use in

Licensed Under Creative Commons Attribution CC BY

concrete production, design of embankments in road construction, waste stabilization and solidification, manufacturing bricks, tiles, kitchen counter tops, cellular concrete, geopolymers etc. In case of geopolymers fly ash is used along with a binding material such as bentonite (naturally occurring clay). For this research fly ash was brought in from the nearest thermal power plant in Ropar.

Procedure

The different mixes in Table 2 tested were designed in such a way to conform to the properties (Table 3) required by a barrier material in a landfill. The effect of the flyash additions on the mixture is reflected by its capability of adsorption. In order to get an adequate silt-bentonite-flyash mixture, an investigation on geotechnical properties was carried out in this study for different mixtures. Using Oedometer test, Proctor test, sieve analysis etc the adequate silt-bentonite-flyash mixture, which satisfies the conditions of permeability (Table 3), was found out. These results were also confirmed by batch adsorption test using Atomic Adsorption spectrophotometer.

Table 2: Mixtures used for analysis of research

Sample	Silt (%)	Flyash (%)	Bentonite (%
1	100	0	0
2	95	0	5
3	85	10	5
4	75	20	5
5	65	30	5
6	90	0	10
7	80	10	10
8	70	20	10
9	60	30	10
10	85	0	15
11	75	10	15
12	65	20	15
13	55	30	15

4. Results/Discussion

The Table 3 gives out the list of experiments and the properties observed on the above stated 13 samples

Table 3: Properties required by a liner material in landfill

Experiment	Procedure/Equipment	Properties observed
Proctor Test	Standard proctor test as per IS 2720	Optimum Moisture Content (OMC) Maximum Dry Density
Liquid Limit	As per IS 2720	Liquid Limit(LL)
Plastic Limit	As per Is 2720	Plastic Limit(PL) Plasticity Index (PI)
Specific Gravity	Using Pycnometer as per IS 2720	Specific Gravity Dry density
Hydrometer	As per IS 2720	Particle grain size distribution
Shrinkage Limit	As per IS 2720	Shrinkage Limit
Consolidation Test	As per IS 2720	Consolidation curve Compression index
Batch Adsorption		Adsorption of solute per solvent Elements: Nickel, Lead, Copper

A. Proctor-Test:

This experiment was performed to determine the relationship between water content and dry density of soil using standard Proctor Test (light compaction) or modified proctor test (heavy compaction), and then to determine the optimum water content and the corresponding maximum dry density for a soil. It also covers the determination of relationship between penetration resistance and water content for a compacted soil.

In the proctor test, the soil is first air dried and then separated into 3 to 4 samples. The water content of each sample is adjusted by adding water (3% to 5% increments or more depending on the type of soil). The soil is then placed and compacted in the proctor compaction mould in three different layers where each layer receives 25 blows of the standard hammer. At the end of the test, after removing or drying of the sample, the dry density and the water content of the sample is determined for each proctor compaction test. Based on the whole set of results, a curve is plotted for the dry unit weight (or density) as a function of water content. From this curve, the optimum water content to reach the maximum dry density is obtained.

From the experiment, it was inferred that the optimum moisture content of simple Sukhna's silt was found to be 1.77 g /cm^3 which increased with the increase in percentage of bentonite. It was also observed that the value of maximum dry density decreases with increase in percentage of flyash, keeping the percentage of bentonite constant.

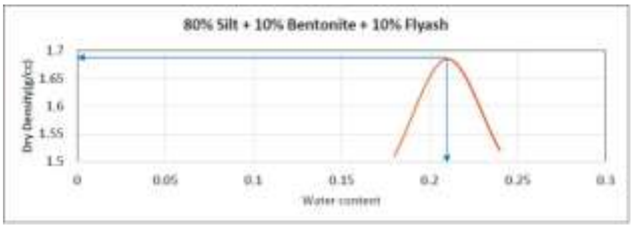

Figure 1: Calibration of Optimum Moisture Content of all mixtures

Table 4: Properties observed for OMC/MDD for all mixtures

Silt (%)	Bentonite (%)	Flyash (%)	OMC	MDD (g/cc)
100	0	0	0.17	1.77
95	5	0	0.18	1.71
90	10	0	0.20	1.66
85	15	0	0.21	1.71
85	5	10	0.20	1.66
75	5	20	0.20	1.61
65	5	30	0.22	1.59
80	10	10	0.21	1.69
70	10	20	0.20	1.58
60	10	30	0.20	1.57
75	15	10	0.22	1.63

Licensed Under Creative Commons Attribution CC BY

65	15	20	0.22	1.61
55	15	30	0.24	1.46

From the results (Table 4):

- It is found that the Optimum Moisture Content (OMC) increases with increase in percentage of Bentonite.
- It was observed that the value of Maximum Dry Density (MDD) decreases with increase in percentage of flyash, keeping the percentage of bentonite constant.

B. Atterberg Limits:

They are a basic measure of the critical water contents of a fine-grained soil: its shrinkage limit, plastic limit and liquid limit. As a dry, clayey soil takes on increasing amounts of water, it undergoes distinct changes in behaviour and consistency. Depending on the water content of the soil, it may appear in four states: solid, semi-solid, plastic and liquid. In each state, the consistency and behaviour of a soil is different and consequently so are its engineering properties. Thus, the boundary between each state can be defined based on a change in the soil's behaviour.

A. *Liquid Limit*: The liquid limit of a soil is the moisture content, expressed as a percentage of the weight of the oven-dried soil, at the boundary between the liquid and plastic states of consistency. The moisture content at this boundary is arbitrarily defined as the water content at which two halves of a soil cake will flow together, for a distance of ½ in. (12.7 mm) along the bottom of a groove of standard dimensions separating the two halves, when the cup of a standard liquid limit apparatus is dropped 25 times from a height of 0.3937 in. (10 mm) at the rate of two drops/second. From the results (Table 5):

- It is found that on increasing the composition of bentonite in the mix against silt the Liquid increased dramatically.
- Also, it is found that for constant bentonite, with increase in flyash against decrease in silt, the change observed in Liquid is negligible.

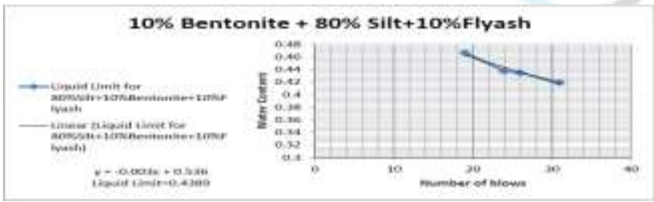

Figure 2: Calibration of Liquid limit of various mixtures

Plastic Limit: The Plastic Limit of a soil is the moisture content, expressed as a percentage of the weight of the oven dry soil, at the boundary between the plastic and semisolid states of consistency. It is the moisture content at which a soil will just begin to crumble when rolled into a thread 1/8 in. (3 mm) in diameter using a ground glass plate or other acceptable surface. It is also used to determine the plasticity index which is the numerical difference between liquid limit and plastic limit and is a dimensionless number. From the results (Table 5),

- It is found that on increasing the composition of bentonite in the mix against silt the Plastic Limit increases.
- On keeping the composition of bentonite constant and increasing the composition of flyash against silt leads to a minor increase in plastic limit, except in case of mixtures with 15s% bentonite.

B. *Shrinkage Limit*: The maximum water content expressed as percentage of oven dry weight at which any further reduction in water content will not cause a decrease in volume of the soil mass but an increase in water will increase the volume. It is the minimum water content at which a soil is still in saturated condition. It is the state which acts as boundary between semi solid state and plastic state. From the results (Table 5)

- It is found that on increasing the composition of bentonite the shrinkage limit increases gradually.
- Further, it is found that the effect of flyash in the mixture varies with the amount of bentonite in the mixture.

Table 5: Properties observed in Atterberg limit experiment of all mixture

Silt (%)	Bentonite (%)	Flyash (%)	LL	PL	PI	SL
100	0	0	29.40	21.50	7.90	13.50
95	5	0	33.58	22.90	10.68	12.22
90	10	0	53.41	37.80	15.61	22.21
85	15	0	65.70	47.10	18.60	27.13
85	5	10	34.38	25.01	9.37	15.67
75	5	20	39.54	29.90	9.64	22.26
65	5	30	38.69	29.75	8.94	20.65
80	10	10	43.89	29.87	14.02	15.09
70	10	20	44.64	30.73	13.91	16.84
60	10	30	46.36	32.47	13.89	19.58
75	15	10	66.60	47.86	18.74	37.20
65	15	20	65.15	45.50	19.65	34.90
55	15	30	66.40	46.60	19.80	33.73

C. Specific Gravity:

The pycnometer was used for determination of the specific gravity of soil particles of both fine grained and coarse-grained soils. The specific gravity of soil is determined using the relation between M_1, M_2, M_3 and M_4

Where M_1= mass of empty Pycnometer
M_2= mass of pycnometer with dry soil
M_3= mass of the pycnometer and soil and water (After removing air using vacuum)
M_4= mass of Pycnometer filled with water only
Specific Gravity of Silt, Bentonite and Flyash are found to be 2.61, 2.83 and 2.174 respectively. Specific gravities of all the other tested mixtures are given in table 6

Licensed Under Creative Commons Attribution CC BY

Table 6: Determination of specific gravity of all mixtures

Silt (%)	Bentonite (%)	Flyash (%)	Specific Gravity
100	0	0	2.61
95	5	0	2.62
90	10	0	2.63
85	15	0	2.64
85	5	10	2.58
75	5	20	2.53
65	5	30	2.49
80	10	10	2.59
70	10	20	2.54
60	10	30	2.50
75	15	10	2.60
65	15	20	2.56
55	15	30	2.51

D. Hydrometer:

Hydrometer was done prior to sieve analysis to check for the grain size distribution of silt sample from Sukhna lake. It is a process by which fine grained soils, silts and clays are graded. Hydrometer analysis is performed if the grain size is too small for sieve analysis. A hydrometer is usually made of glass and consists of a cylindrical stem and a bulb weighted with mercury or lead shot to make it float upright. The liquid to test is poured into a tall container, often a graduated cylinder, and the hydrometer is gently lowered into the liquid until it floats freely. The point at which the surface of the liquid touches the stem of the hydrometer correlates to specific gravity.

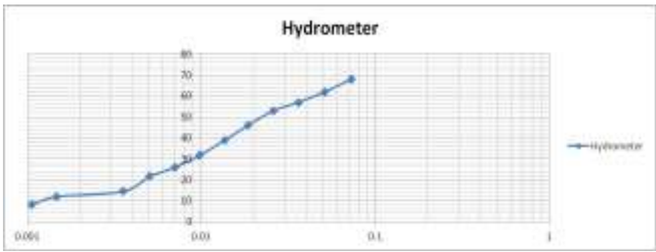

Figure 3: Grain Size Distribution of Sukhna's Silt

Table 7: Grain Size Calculation of Sukhna's Silt

Elapsed time t(min)	Hydrometer Reading $R_{h'}$	Temp °C	Correction C	$R_h=R_{h'}+C_m$	Effective Depth H_e	Factor F	Particle Size D(mm)	$R=R_{h'}+C$	% Finer
0.5	13.5	23	0.5	14	15.06	1339	7.30E-02	14	68
1	13.5	23	0.5	14	15.06	1339	5.10E-02	14	62
2	13.5	23	0.5	14	15.06	1339	3.60E-02	14	57
4	13.5	23	0.5	14	15.06	1339	2.59E-02	14	53
8	12.5	23	0.5	13	15.42	1339	1.85E-02	13	46
15	12	23	0.5	12.5	15.6	1339	1.37E-02	12.5	39
30	11	23	0.5	11.5	15.96	1339	9.76E-03	11.5	31.7
60	9	23	0.5	9.5	16.68	1339	7.05E-03	9.5	26
120	8	23	0.5	8.5	17.04	1339	5.04E-03	8.5	21.6
240	7	24	1	7.5	17.22	1323	3.54E-03	8	14.5
1440	5.5	24	1	6	17.76	1323	1.47E-03	6.5	12
2880	4.5	24	0.5	5	18.3	1323	1.05E-03	5	8.3

The Grain size distribution graph (Fig 3) shows the grain size distribution of the silt sample from which it can be inferred that a sieve analysis was not required for the silt sample.

E. Consolidation Test (Oedometer):

This test is performed to determine the magnitude and rate of volume decrease that a laterally confined soil specimen undergoes when subjected to different vertical pressures. The data obtained from this test is used to determine the compression index, consolidation pressure and the coefficient of consolidation. From the results (Table 8) it can be inferred that;

- With increase in composition of bentonite in the mixture the corresponding coefficient of consolidation decreases whereas a similar analogy cannot be drawn for the change in proportion of flyash in the mix.
- Similarly, the permeability of the mix for different loading conditions decreases significantly with increase in proportion of bentonite in the mix.
- With increase in proportion of flyash keeping bentonite constant there is an increase in permeability indicating that with increase in flyash the soil sample loses its adhesive character.

Table 8: Comparison of Permeability Constant across various mixture

Silt (%)	Bentonite (%)	Flyash (%)	Cv	K(cm/s)
100	0	0	5.40E-04	1.30E-06
95	5	0	9.14E-04	3.37E-07
90	10	0	6.00E-04	4.19E-09
85	15	0	5.91E-04	4.50E-10
85	5	10	5.13E-04	1.37E-07
75	5	20	9.13E-04	3.56E-07
65	5	30	8.28E-05	5.30E-07
80	10	10	1.82E-04	1.44E-10
70	10	20	4.84E-04	1.66E-10
60	10	30	3.95E-04	2.75E-10
75	15	10	3.97E-04	2.40E-10
65	15	20	5.97E-04	5.02E-10
55	15	30	6.88E-04	6.69E-10

Licensed Under Creative Commons Attribution CC BY

- It was also observed that all the mixes conform to the permeability requirements of those required by a liner layer of a landfill.

The Graph below depicts the behaviour of a soil while loading and unloading several weights ranging from 0.5 kg/cm^2 to $8kg/cm^2$

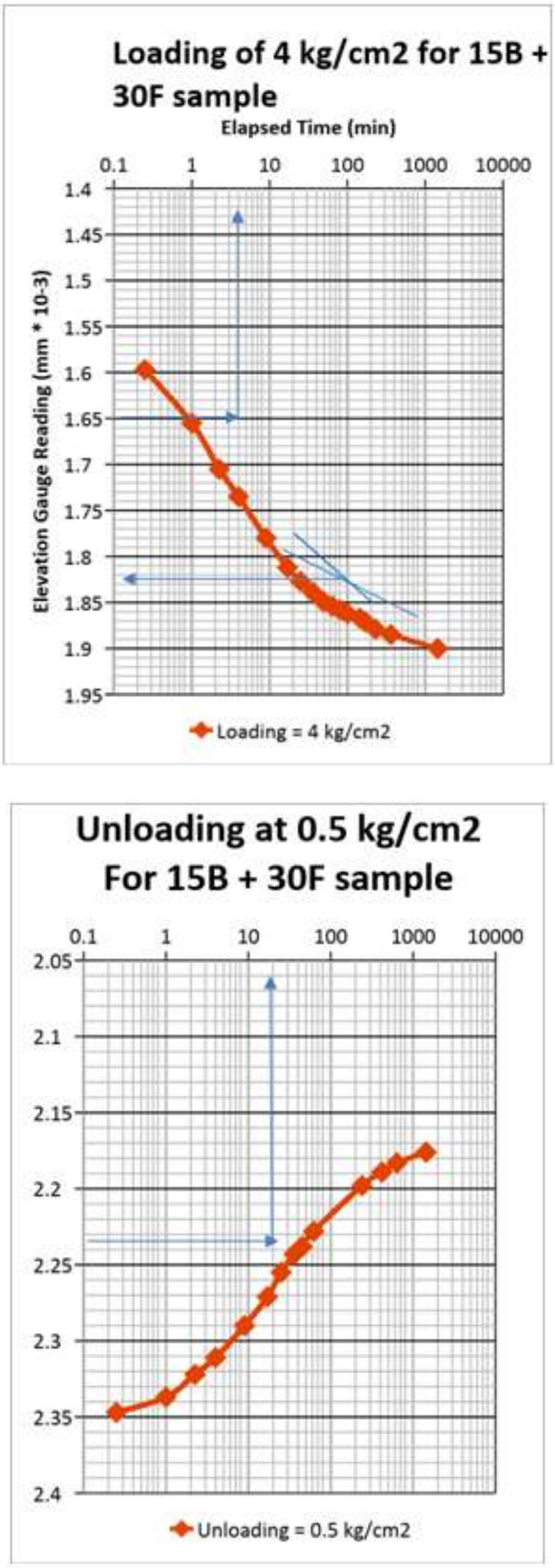

Figure 4: Calibration of loading and unloading of a mixture at different weights

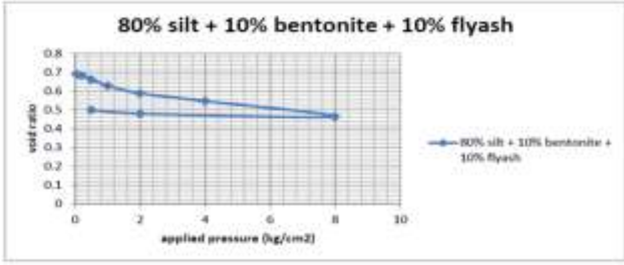

Figure 5: Analysis of trend of a mixture after applying series of load using oedometer apparatus

F. Batch Adsorption:

Permeability was one of the important factors required for the mixture to be used as a liner material in landfill. However, it is very important to signify how the mixture used in design of liner reacts with the major components present in leachate. When wastewater is discharged into soil, it seeps through the soil before it progresses downward into groundwater, or it flows past soil surface to lowland. Many studies have found that heavy metals can be adsorbed by soils. Accordingly, soils are natural materials that play a role in treating wastewater, before the metal seep into groundwater, or flow into other areas or rivers.

Batch Adsorption test was performed using Atomic Adsorption Spectrophotometer to check the concentration adsorption of the following major elements: Chromium, Nickel, Lead, Copper and their analysis were done using the following isotherms

- Freundlich Isotherm
- Langmuir Isotherm
- Tempkin Isotherm

The data obtained from this test is used to determine the maximum concentration per solute obtained after passing through the mixture designed for liner material in landfill.

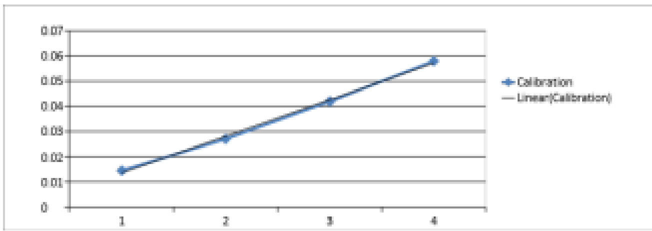

Figure 6: Calculation of slope of Adsorbant

Licensed Under Creative Commons Attribution CC BY

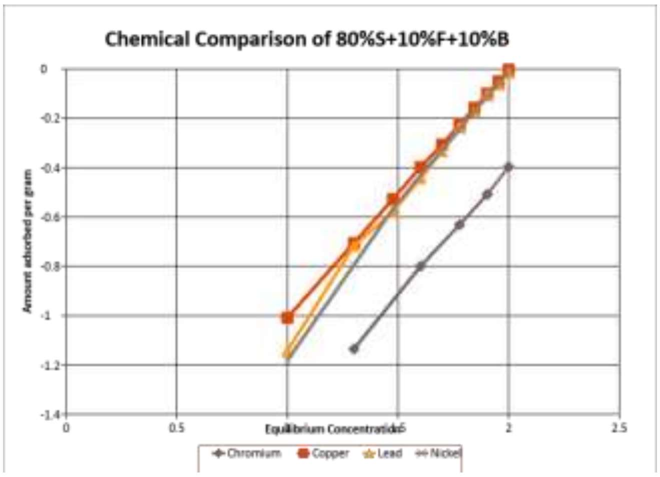

Figure 7: Equilibrium Concentration of all mixtures for Elements: Chromium, Copper, Lead, Nickel via Freundlich adsorption isotherm

5. Conclusion

From the different experiments and tests (Table 3), it was found that mixture having bentonite concentration around 10 % shows maximum adsorption per solute (at a concentration say 25ppm) compared to other mixes. This is because on increasing the proportion of bentonite from 0 to 10 there is a gradual decrease in permeability, however, with further increase in proportion of bentonite in the mix no significant change is observed. Increasing bentonite also leads to a considerable increase in liquid limit and shrinkage limit.

It was also observed that though the results obtained from the mixes with even 5% Bentonite fall within the required range for the basic design of landfills. But being very close to threshold value (rather just crossed) and even adsorption of chemical compounds over various concentrations of sample with 5% bentonite was not uniform becomes a reason to prefer the mixture with 10% bentonite over it.

The percentage of flyash did not interfere much with the properties required for landfill but with increase in percentage of fly ash it was found that the mix started losing its clayey properties, although they remained in the required range.

With 10 % Bentonite, working on several sub-Mixes of Flyash & silt: It was observed that 10 % Bentonite with 10% flyash and 80% Silt is best suited for the design because of the following reasons:

- The results of this mixture obtained are uniform and shows consistent adsorption of various concentrations of solvent which means that it is easy to predict its behaviour in the field and is much safer and suitable for the design of landfill.
- On comparing its results with other mixtures (10% bentonite + 20% flyash and 10% bentonite + 30% flyash), it was observed that the results of the mixture obtained were not uniform. For eg: for 10 % Bentonite with 30 % flyash, it has a steep slope due to which at less concentration, its adsorption per solute is less as compared to higher concentration of chemicals. Mixture of 10 % Bentonite with 20 % Flyash also gives a similar inference, but with decrease in magnitude of non-uniformity.

After all cost considerations and availability of different materials for the mix it is advisable to use mixture of 80 % silt with 10 % Bentonite and 10 % flyash and remaining 80% silt (from Sukhna lake) as a liner material in a landfill design.

References

[1] IS Code: 2720
[2] Guidance Document #691 : Separatory Liner/Leachate Collection Systems
[3] Prediction of Heavy Metal Removal by Different Liner Materials from Landfill Leachate: Modeling of Experimental Results Using Artificial Intelligence Technique
[4] Landfill Liner and Cover Systems: Design Guidelines
[5] Landfill Liners and Covers: PVC Geomembranes in Municipal Waste Landfill Liners and Covers
[6] Design and Construction of liner system
[7] Soil Mechanics: Author B C Punmia
[8] Manual of soil laboratory: Testing by FGS
[9] Batch Sorption Experiments: Langmuir and Freundlich Isotherm Studies for the Adsorption of Textile Metal Ions onto Teff Straw Agricultural Waste Landfill Leachate Composition

Licensed Under Creative Commons Attribution CC BY