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Design of Amended Landfill Liner Using Nano Silica

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Abstract - *Landfill liners are provided to prevent the movement of leachate to underground water. So the materials which are used should have low hydraulic conductivity. This study is an attempt to use the site soil, Nano silica and bentonite mixture as a potential liner. In this, the variation in properties such as hydraulic conductivity, dry density, OMC, Atterberg's limits etc. was studied by mixing Nano silica an bentonite with site soil in various percentages. The results show that the mix M6 & M5 has the least hydraulic conductivity that satisfies the property of a liner. Also due to the increase in Nano silica and bentonite content the OMC increases and dry density decreases. Therefore the property of mixes shows that it can be used as a liner in the landfill.*

***Key Words*: Landfill liner, bentonite, Nano silica**

1. INTRODUCTION

In all developing and developed countries, the waste disposal is the most serious environmental problem. One of the important solutions to this problem is the waste disposal by landfills. Landfills are the solid waste disposal systems which are designed by isolating the waste from the surface by providing an impermeable liner system to prevent the flow of leachate coming from the waste to the groundwater. Mainly two types of liner systems are used i.e. GCL (Geosynthetic clay liner) and CCL (Compacted clay liner). Designing and maintaining of a landfill are one of the most important factors. Low permeable clays are used for the construction of liners. CCL is composed of any native soil or blends of soil and bentonite or any clay with low hydraulic conductivity. If the site soil should not satisfy the properties of liner other materials with low permeability are mixed to form amended soil liners. This study is an attempt to use Nano silica with the bentonite and site soil as a liner. Nowadays Nano technological study gave a modern approach in the field of geo-techniques. In recent years, the Nano additives have made a considerable effect in many civil engineering applications.

1.1 Literature Review

Craig H. Benson et al (1994) described a data base which was used to evaluate relation between permeability, compositional factors, and compaction terms and to determine the minimum values for soil properties that are likely to yield mean permeability ≤1×10-7 cm/s. The material specifications obtained from the study is presented in table - 1.

Table -1: Liner Specification

Property	Minimum (%) for k≤1.00x10^{-7} cm/s
Liquid Limit	25-30
Plasticity Index	10-30
% Fines	30
%Clays	15
Activity	0.3

Craig H. Benson and John M. Trast (1995) conducted permeability tests on thirteen compacted clay liners at landfills throughout the U.S. and showed that a distinct set of zones exist in the compaction curve that correspond to similar permeability for all of the soils. These zones fall roughly parallel to contours of constant initial saturation , with a lower hydraulic conductivities occurring at higher initial saturation. A graph of hydraulic conductivity vs. initial saturation showed an inverse relationship between them and illustrated that lower permeability are achieved for higher compactive effort.

Emy Poulose et al. ,(2013). Landfills are highly engineered waste containment systems, designed to minimize the impact of solid waste on the environment and human health. In modern landfills, the waste is contained by liner and cover system. The greatest threat to ground water posed by modern landfills is leachate. Leachate consists of water and water soluble compounds in the refuse that accumulate as water moves through the landfill. Barrier layer in liner system are used to prevent the flow of leachate out of landfill. These are normally constructed with very low permeability clay. When low permeability clay is not available locally, in-situ soils may be mixed with medium to high plasticity imported clay, or commercial clays such as bentonite to achieve the required low hydraulic conductivity. Such liners are called amended soil liners. In this work, two amended soil liners are designed one clay soil from Kuttanad region, fine sand and bentonite and the other with kaolinite, fine sand and bentonite.

Shyla Joseph.A et al.,(2017). Landfill liner system has great importance in preventing the movement of leachate to underground surfaces. The study makes an attempt to improve the locally available dump yard site soil using bentonite and zeolite mixtures. The variation in properties such as permeability (layered form) , dry density, OMC, consistency limits etc were studied. The result of permeability test shows that mix containing 40% dump yard site soil, 35% bentonite and 25% zeolite has the least permeability. Therefore the geotechnical properties make bentonite and zeolite mix an innovative material for liners in landfills.

2. METHODOLOGY

The samples were collected and the laboratory tests were conducted to study the geotechnical properties of the collected samples. Then a definite mix proportion was selected based on the literature. Selected mix proportions are shown in Table 1. Laboratory tests were conducted to study about the variation of dry density, OMC, and permeability. After conducting test a final mix has to be selected as a liner material

Table -2: Mix Combination

MIX	Combination
M1	80%Local Soil+10%Bentonite+10%Nano Silica
M2	80%Local Soil+15%Bentonite+5%Nano Silica
M3	60%Local Soil+20%Bentonite+20%Nano Silica
M4	60%Local Soil+25%Bentonite+15%Nano Silica
M5	40%Local Soil+30%Bentonite+30%Nano Silica
M6	40%Local Soil+35%Bentonite+25%Nano Silica

2.1 Materials and Properties

1. Soil Sample

The soil samples are collected from Kollam. The soil was tested in the laboratory to determine the index properties. The index properties are showed in Table 3.

Table -3: Properties of samples

Soil Properties	Values Obtained	
	Sodium Bentonite	Local Soil
Specific gravity	2.6	2.63
Liquid limit W_L(%)	336	48.4
Plastic limit w_P (%)	40	25.8
Plasticity Index I_P(%)	296	22.6
IS Classification	CH	CI
Permeability K(cm/sec)	20.5×10^{-9}	1.53×10^{-5}
OMC (%)	40	21.49
Dry density (g/cc)	1.256	1.49
Percentage of clay	69	27
Percentage of silt	24	57
UCC strength (kg/cm^2)	0.173	0.121

2. Bentonite

Bentonite is a type of clay with very high swelling capacity by absorbing water. Also, it has high ion exchange capacity and low hydraulic conductivity. So it can be used as a liner in the base of landfills. Nowadays soil-bentonite mixes are widely used as liners in waste containment due to the low permeability of bentonite clay. Commercially two types of bentonite are available, calcium bentonite and sodium bentonite. In this study, sodium bentonite was used. It was collected from Associated Chemicals Kochi. Its properties are listed in Table 3.

3. Nano Silica

Silicon dioxide Nanoparticles are also called Nano silica. Generally, Nano silica is divided into P-type and S-type. The P-type consists of a large amount of Nano pore having a pore rate of 0.61ml/g. The S-type have smaller surface area. It appears in the form of white particle as shown in fig 1. The properties of Nano silica was listed in Table 4.

Table -4: Properties of Nano silica

Material	Contents (%)
SiO_2	99.7
Ti	.012
Ca	.007
Na	.005
Fe	.002

Fig -1: Nano Silica

2.2 Literature Review

The Experimental studies involves

1. Compaction test

Standard compaction method was used to determine the maximum dry density (MDD) and optimum moisture content (OMC) of bentonite-Nano silica mixture in various proportions with site soil

2. Permeability Test

Permeability is the property of soil which allows water to flow through its voids. The permeability of bentonite-Nano silica mixture with site soil is determined using falling head permeability test.

3. Atterberg's Limits

Atterberg's limits were calculated according to IS (2720: Part 5- 1985). For doing the liquid limit test, plastic limit test, the

samples were prepared by mixing local soil, bentonite and Nano silica.

4. Unconfined Compression Test

Unconfined compression test was conducted according to IS 2720 (part 10) -1973. The samples were prepared at optimum moisture content and maximum dry density which was obtained from compaction test.

3. RESULT AND DISCUSSION

1. Compaction test

Table -5: Compaction Test Results

MIX	OMC (%)	DRY DENSITY (g/cc)
M1	36.05	1.24
M2	37.5	1.23
M3	54	1.12
M4	57	1.1
M5	61	1.05
M6	63	1.01

Optimum moisture content increases and maximum dry density decreases with increase in bentonite and Nano silica content

2. Permeability Test

Table -6: Permeability Test Results

Mix	Coefficient of Permeability(cm/sec)
M1	1.506×10^{-5}
M2	1.394×10^{-5}
M3	2.309×10^{-6}
M4	5.975×10^{-6}
M5	8.678×10^{-7}
M6	8.69×10^{-8}

The coefficient of permeability decreases with increase in bentonite and Nano silica content. Least value for the coefficient of permeability obtained is 8.678×10^{-7} & 8.69×10^{-8} it is for the M5 & M6 mix. This is due to the high specific area of bentonite and Nano silica, also due to high porous nature of Nano silica which absorbs more water which fills the pores in soil structure and lowers the soil porosity and hydraulic conductivity.

3. Atterberg's Limit

Table -7: Atterberg's Limits Results

MIX	LL	PL	PI
M1	60	46	14
M2	64	47	17
M3	98	80.37	17.63
M4	105	85.75	19.25
M5	119	94	25
M6	130	101	29

4. Unconfined Compression Test

Table -8: Unconfined Compression test Results

Property	M1	M2	M3	M4	M5	M6
UCS (kN/m^2)	185.05	188.65	194.635	196.32	202.00	234.625

5. Liner Criteria

Table -9: Liner Criteria

Property	Values	M1	M2	M3	M4	M5	M6
Plasticity Index (PI)	10-30%	14	17	17.63	19.25	25	29
Liquid Limit	25-30%	60	64	98	105	119	130
Permeability	≤ 1 x 10 -7 cm/sec	1.506×10^{-5}	1.394×10^{-5}	2.309×10^{-6}	5.975×10^{-6}	8.678×10^{-7}	8.69×10^{-8}
UCS (kN/m^2)	200	185.025	188.65	194.635	196.32	202.00	234.625

Based on the liner criteria, mix M5 & M6 can b used as a liner.

3. CONCLUSION

Following conclusions are obtained from the present Experimental studies

- Various combination mixes were worked out and out of that mixes M6 (40% local soil+35%bentonite+25% Nano silica) & M5 (40% local soil+30%bentonite+30% Nano silica) was found to be the one with least permeability.
- Plasticity index is alsofound to be in between 12 & 30
- Due to the high specific area of bentonite and Nano silica which tends to absorb more water which fills the pores in soil structure and lowers the soil porosity and hydraulic conductivity.
- Therefore M6 & M5 mix can be used as clay liner

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