Characteristic Study on Liner Properties Using Paper Mill Sludge and Sepiolite

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***Abstract*—Any matter leftover after its primary use becomes a waste. Most of the ecological pollution faced by the world today is due to the massive production of waste. Landfills are the most commonly designed and monitored method of organized waste disposal that isolates waste from the surrounding environment. It consists of a liner system at the bottom to prevent the percolation of leachate to the underlying aquifers. For this the liner should have low permeability, preferably less than 10^{-7}cm/s. Clayey soil is generally used as a liner. Where in clayey soil is not available alternative materials are used. In the particular study, main components of the liner are laterite soil, paper mill sludge and sepiolite. Paper mill sludge is a byproduct of paper industry whose disposal is difficult. Sepiolite is a fine grained mineral having good strength characteristics. The materials are mixed with soil in varying proportions and optimum mix required is determined. Parameters considered for the study are permeability, Atterberg limits, strength and compaction characteristics.**

Keywords*—*Landfill, Liner, Paper mill sludge, permeability

I. Introduction

Waste management is a complex problem in developed and developing countries. Improper waste management leads to spreading of diseases, aesthetic deterioration, soil, water and air pollution. The results of improper waste management includes dumping of garbage to water bodies, dirty public areas leading to different kinds of diseases. The problem is increasing day by day due to rapid increase in population, industrial developments and changes in eating habits leading to the massive production of disposable containers. Waste is dumped to open areas without considering its environmental considerations. Landfills are the sites used for the disposal of waste materials. The wastes which come to a landfill include solid waste, agricultural waste, construction and demolition waste. It consists of a liner system at the bottom, daily cover, methane gas recovery system, cell and leachate collection system. The cover system provided at the top prevents the infiltration of rainfall to the waste. The waste in landfill produces leachate. The liner prevents the percolation of leachate to the underlying aquifers and prevent them from contamination. In order to serve as an effective barrier, it should have low hydraulic conductivity. Generally compacted clayey soil is used to serve this purpose. But now a days due to the lack of availability of clay, alternative materials are used. Landfills receive different types of waste including municipal solid waste (MSW), agricultural waste, construction and demolition waste and many others.

A. LINER SYSTEM

In containment landfill, waste is dumped on an engineered layer of soil known as liner system. Liners are made with materials having the desirable properties meeting the regulations set up by the Pollution Control Board. Liners are designed such that the leachate seeps out at a very low rate and get diminished. Liners may be made of compacted clay liner (CCL) or geosynthetic clay liner (GCL). Natural, synthetic and combination of natural and synthetic materials can be used as landfill liner material. Natural material used for liner construction is mainly clayey soil due to its low hydraulic conductivity. Now a days alternative materials such as bentonite, fly ash, wood ash are been used now a days.

B. SPECIFICATIONS OF LINER MATERIAL

According to the Environmental Protection agency (EPA); 1989, so liners should be built such that their hydraulic conductivity is less than or equal to 1 x 10^{-7}cm/s. The minimum specifications for a material to attain the hydraulic conductivity value less than or equal to 1 x 10^{-7}cm/ is presented in Table I.

TABLE I. SPECIFICATIONS OF LINER MATERIAL

Property	Minimum values to attain, $k \leq 1 \times 10^{-7}$ cm/s
Liquid limit	>20
Plasticity index	>7-15
% fineness	>30
% clay	>15
Activity	0.3

C. SCOPE

In places where natural clayey soil is not available, alternative materials has to be developed to serve the purpose of a landfill liner.

II. MATERIALS USED

The materials used for the study were laterite soil, paper mill sludge and sepiolite. The different properties of the materials are given below.

A. *Laterite Soil*

The laterite soil used for the study was collected from Kottayam district. It was found to have a brown colour. Laterite soil passing through 4.75mm IS sieve was used for the study. The sample used for the study is shown in Fig. 1.

Fig. 1: Soil used for the study

B. *Paper Mill Sludge*

The paper mill sludge (PMS) required for the study was collected from Canara Mills, Kottayam. It was collected in solid form. It was compacted and the materials passing through 600 micron IS sieve was used for the study. The sludge was found to have a grey colour. Paper mill sludge is known to have low hydraulic conductivity and hence it is been used as cover and liner for landfills. The sludge used for the study is shown in Fig. 2.

Fig. 2 : Paper mill sludge

C. *Sepiolite*

Sepiolite is a fine grained mineral which contains magnesium silicate. It was found to be white in colour and is formed by thin elongated chain type crystal structures. It does not flocculate with electrolytes and remain stable at high temperatures. It has good adsorption characteristics. It is used as a drilling fluid in borehole stabilization. It has good strength characteristics. The material used for the study was collected from Chennai and is shown in Fig. 3.

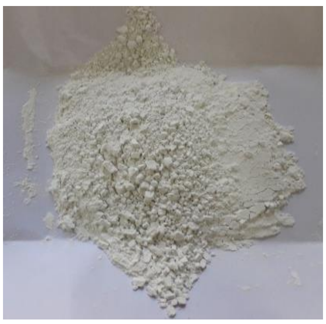

Fig. 3: Sepiolite

III. METHODOLOGY

The soil was mixed in varying proportion with paper mill sludge and sepiolite and optimum mix required was determined from the permeability test. The various soil mixes used for the study is shown in Table II.

TABLE II. MIX COMBINATIONS

Combination	Notation
80% soil + 10% PMS + 10% sepiolite	S1
80% soil + 15%PMS +5% sepiolite	S2
60% soil +20% PMS +20% sepiolite	S3
60% soil +25% PMS +15% sepiolite	S4
40% soil +30% PMS + 30% sepiolite	S5
40% soil + 35% PMS + 25% sepiolite	S6

IV. TEST METHODS

A. *Atterberg Limits*

The basic measure of critical water content of fine grained soil is their Atterberg limits or consistency limits. It includes liquid limit, plastic limit and shrinkage limit. The water content at which soil changes from one state to other is called Atterberg limit or consistency limits. The liquid limit was determined using Casagrande apparatus and plastic limit was determined by rolling a thread of 3mm diameter. The test was performed as per IS: 2720 (Part 5)-1985.

B. *Compaction Test*

Standard Proctor test was done to determine the optimum moisture content (OMC) and maximum dry density (MDD). The test was performed as per IS: 2720 Part 7.

C. *Permeability Test*

The property of soil which allows the seepage of fluid through the interconnecting voids is termed as permeability. For a liner, the key factor is its permeability. Falling head permeability test was conducted. The soil is mixed with varying proportion of paper mill sludge and sepiolite. The test was conducted as per IS: 2720 Part 17, 1986.

D. *Strength Test*

Strength was determined using triaxial testing apparatus. Shear strength parameters (cohesion and angle of internal friction) can be determined from this test and hence strength can be computed.

IV RESULTS AND DISCUSSIONS

The various geotechnical properties of soil was determined. The properties of soil are given in Table III.

TABLE III. PROPERTIES OF SOIL

Sl.No	Property	Test Method	Result
1.	Initial moisture content	Oven drying method	22%
2.	Specific gravity	Pycnometer method	2.65
3.	Liquid limit	Atterberg limits	47%
4.	Plastic limit		24%
5.	Plasticity index		23%
6.	Shrinkage limit		
7.	% clay	Hydrometer analysis	17
8.	% silt		23
9.	% sand		56
10.	% gravel		4
11.	Optimum moisture content	Standard Proctor test	19%
12.	Maximum dry density		1.73g/cm^3

The various properties of paper mill sludge used for the study are shown in Table IV. The sludge used for the study was air dried.

TABLE IV. PROPERTIES OF PAPER MILL SLUDGE

Sl No	Property	Result
1.	Specific gravity	1.8
2.	Optimum moisture content	54%
3.	Maximum dry density	0.89g/cm^3
4.	Hydraulic conductivity	7.7 x 10^{-7} cm/s

The properties of sepiolite clay used for the study are given in Table V.

TABLE V. PROPERTIES OF SEPIOLITE

Sl No	Property	Result
1.	Specific gravity	2.3
2.	Liquid limit	120%
3.	Plastic limit	70%
4.	Plasticity index	50%
5.	% clay	52
6.	% silt	48

The key property of a landfill liner is permeability. Permeability test was conducted for different soil samples. The results for permeability test is given in Table VI.

TABLE VI. PERMEABILITY TEST RESULTS

Mix	Result (cm/s)
S1	1.27 x 10^{-5}
S2	1.56 x 10^{-5}
S3	1.64 x 10^{-6}
S4	3.03 x 10^{-6}
S5	1.48 x 10^{-7}
S6	2.03 x 10^{-7}

From Table 5, it is seen that permeability decreases with the addition of paper mill sludge and sepiolite, up to a limit and the increases slightly. The optimum mix is taken as sample 5 (S5), due to its low permeability value. The decrease in permeability value is because the sludge act as a clay like material. The laterite soil has large voids, the addition of paper mill sludge and sepiolite fill these voids. The filling of voids by these materials makes them impervious thereby reducing the void ratio and hydraulic conductivity.

The results of Atterberg test for different combinations is given in Table VII.

TABLE VII. ATTERBERG TEST RESULTS

Mix	Liquid limit (%)	Plastic limit (%)	Plasticity index (%)
S1	61	27	34
S2	67	29.5	37.5
S3	84	35	49
S4	86	36	50
S5	101	43	58
S6	104	45	59

It is seen that liquid limit increases with the addition of paper mill sludge and sepiolite. The value of plasticity index also increases. The addition of sludge and sepiolite which are clay like materials increases the plasticity characteristics by taking more water to deform and fill the voids making it impervious. Since the plasticity index is less than 65% it produces only lesser number of dessication cracks.

Compaction test was performed on the six samples. The variation in optimum moisture content and maximum dry density was studied. The results of compaction test is presented in the form of graphs for six samples from Figure 4 to 9 respectively.

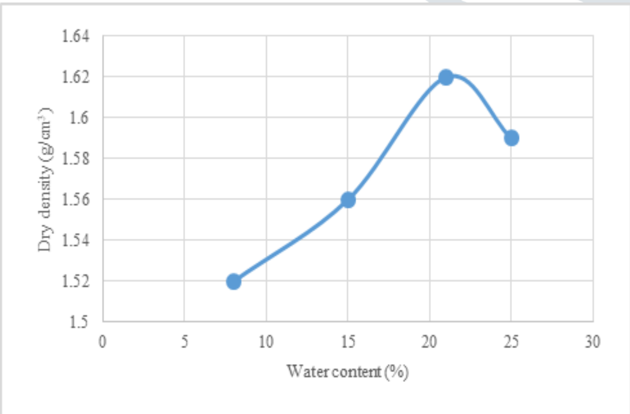

Fig. 4: Compacion curve for S1

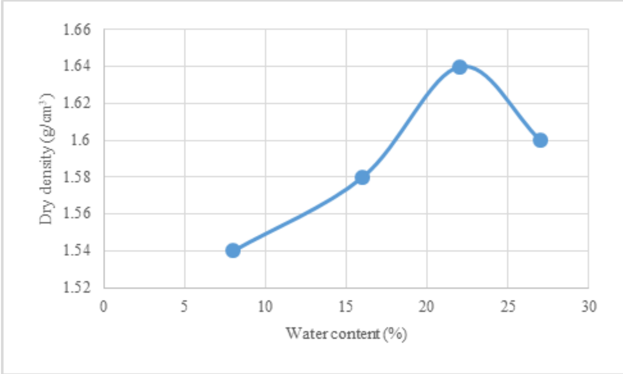

Fig. 5: Compaction curve for S2

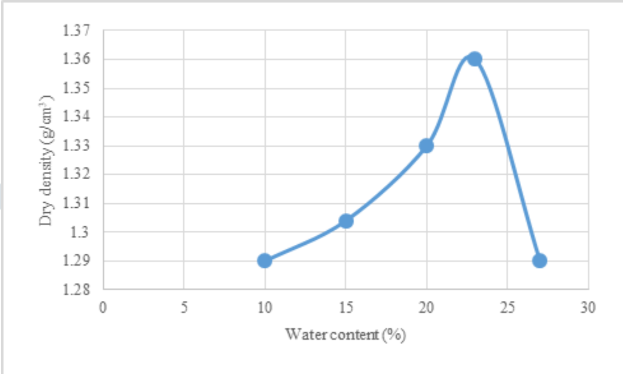

Fig. 6: Compaction curve of S3

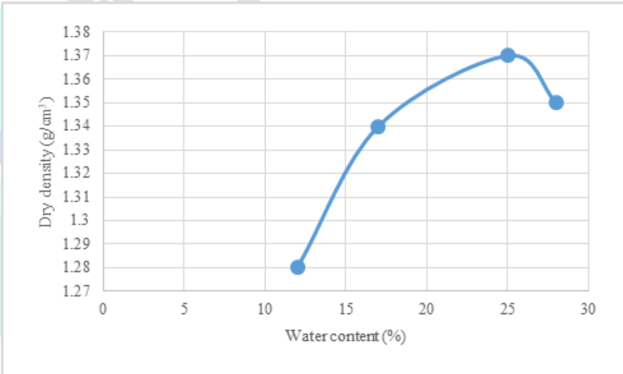

Fig .7 : Compaction curve of S4

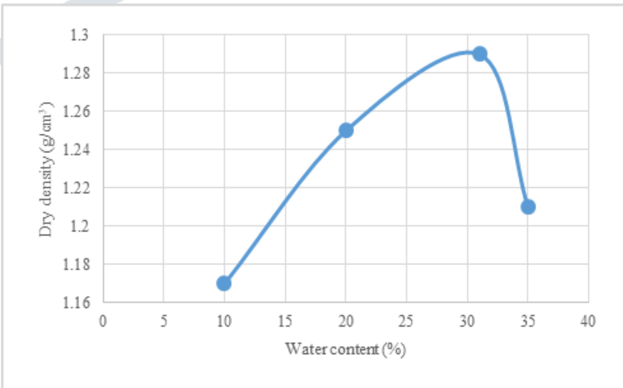

Fig.8: Compaction curve for S5

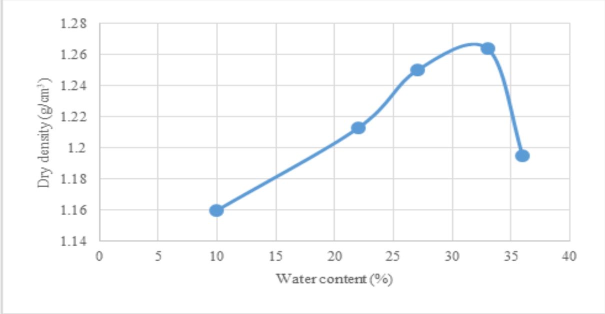

Fig. 9: Compaction curve for S6

From the compaction curves it is seen that the OMC value attained in each case increases as the amount of PMS and sepiolite increases. Also the value of maximum dry density attained decreases. The decrease in dry density with the addition of PMS and sepiolite may be due to the high swelling characteristics of clay that forms a gel known as diffused double layer around the soil particles. The increase in OMC value is due to increase in clay content, as they require more water to coat the soil particles.

Strength was studied using triaxial compression testing machine. The shear stregth of soil under a stress of 1 bar is computed. The results of traxial strength test is presented in Table VIII.

TABLE VIII. STRENGTH RESULTS

Mix	Strength (kPa)
S1	19.4
S2	22.7
S3	40.4
S4	42.5
S5	62.5
56	67.5

It is seen that strength increses with the addition of PMS and sepiolite.

V CONCLUSIONS

Landfill is a common method for waste disposal. Here an attempt was made to produce a landfill liner using laterite soil, paper mill sludge and sepiolite. From the study it is concluded that paper mill sludge and sepiolite can be used as landfill liner materials. The optimum mix required is seen as the one containing 40% soil, 30% paper mill sludge and 30% sepiolite. It is chosen based on the permeability criteria, strength, compation and Atterberg test results. This liner can be used in municipal soild waste landfills (MSW).

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