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EFFECT OF BENTONITE ON HYDRAULIC CONDUCTIVITY OF LANDFILL LINER & PRELIMINARY DESIGN OF LANDFILL

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ABSTRACT: The rapid urbanization, change in consumption pattern and social behavior have increased the generation of municipal solid waste (MSW) in Kerala. Therefore, there is an urgent necessity of improved planning and implementation of comprehensive solid waste management systems for upgrading the environmental scenario of the State. One of the most effective methods for solid waste management is landfill. Our paper aims at a preliminary design of landfill using locally available soil. And there by focuses on the effective solid waste management. Landfill is a cheapest method for waste management, however it has becoming less due to the lack of space available and the leachate leakage into ground water. The paper comes with a solution to this problem by reducing the leachate migration using amended soil as liner material. As a part of decreasing the hydraulic conductivity of liner we choose variable head method in permeability test for experimental study. The locally available soil collected from Guruvayur is having a permeability of 7.30 x 10^{-4} cm/s, which is greater than the limit. So add various percentages of bentonite such that 2%, 4% etc. to the locally available soil to achieve the permeability limit as recommended. It is found that with the addition of 7% of bentonite soil is achieved the required permeability of 9.90 x 10^{-8} cm/s. Preliminary design of landfill is then done by considering the factors such as water table, rate of waste generation and its increase etc. of the proposed landfill location and by evaluating the dimensions, life and capacity.

INTRODUCTION

The current global municipal solid waste generation level is approximately 1.3 billion tonnes per year. And are expected to increase by approximately 2.2 billion tonnes per year by 2025. Throw away culture and open dumping cause a lot of land area will be lost. But these wastes are not properly managed. Within this framework, landfills are a best mechanism for effectively treating and disposing of those wastes at the present time. One of the major issue associated with landfilling is contamination of ground water. A low permeability liner is a solution for preventing the leakage of leachate into the ground water. If available soil is of not a low permeability, the hydraulic property is improved by addition of bentonite. This study mainly focuses on the properties of bentonite enhanced soil and also examines suitability as a liner material.

The main property that is to be satisfied by a liner is that is hydraulic conductivity must be less than 1 x 10^{-7} cm/s. laboratory studies have demonstrated that low permeability is easiest to achieve when the soil is compacted to wet off optimum water content. The minimum requirements recommended to achieve a hydraulic conductivity less than or equal to 1 x 10^{-7} cm/s for most soil liner materials are as follows.[2]

The percentage fine must be between 20-30%, plasticity index must be between 12-30 %, percentage gravel must be less than 30% and maximum particle size should be 25-50mm. if suitable materials are un available locally, local soil can be blended with commercial clays example bentonite to achieve low hydraulic conductivity. Relatively small amount of bentonite can reduce hydraulic conductivity as much as several orders of magnitude.

One should be conscious about using highly plastic soils (soils with grater plasticity indices, 30-40%) as it forms hard clods when the soil is dry and are very sticky when the soil is wet.

MATERIALS AND PROPERTIES

Soil

Soil was collected from Guruvayur. Since the liner is preparing for the landfill site at Guruvayur. Soil passing 4.75 mm sieve was used for this study. The particle size distribution curve of soil passing is shown in Fig.1. Index and engineering properties of soil are found out in the laboratory as per bureau of Indian standard which show in Table 1.

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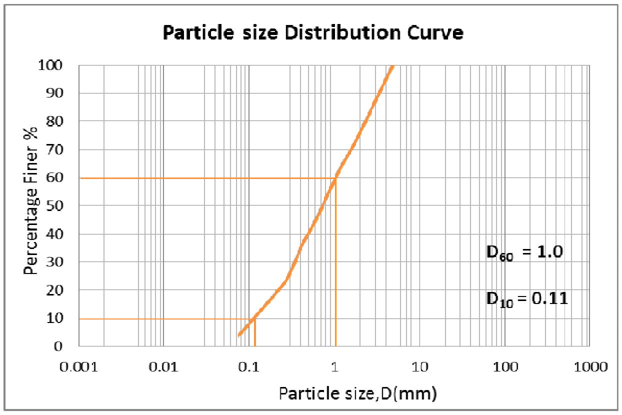

Fig.1 Particle size distribution curve

Table 1. Properties of locally available soil

Properties	Values
Specific gravity	2.67
Liquid limit(%)	20.3
Plastic limit(%)	13.7
Plasticity Index	6.30
Shrinkage limit	7.81
Maximum Dry Density	1.974 g/cc
OMC	13.0%
Permeability (cm/s)	7.3×10^{-4}

Bentonite

Bentonite is naturally occurring clay with high expansion capability and low water permeability. Two types of commercially available bentonites are there. Sodium bentonite is used in this study. The engineering and index properties of bentonite were found out in the laboratory as per Indian standards and are present in Table 2.

Table 2. Properties of Bentonite

Properties	Values
Specific gravity	2.60
Liquid limit(%)	350
Plastic limit(%)	52.4
Plasticity Index(%)	297.6

EXPERIMENTAL PROGRAM

A. Compaction Test

To determine the amount of compaction and the water content required in the field compaction tests done in the laboratory. Standard proctor test were used to carried out to determine the optimum moisture content and maximum dry density of soil with different percentage of bentonite such as 2%, 4% etc.

B. Permeability test

The permeability of soil and bentonite mix is found out by variable head permeability test. For the test the mixture of soil and bentonite is compacted to wet off optimum.

C. Soil as liner material

Resultant mix of liner should have a minimum of 20 to 30% fines and the percentage gravel should not exceed 30%. And the plasticity index should be between 12 and 30% and maximum particle size is restricted to 25-50mm.

RESULTS AND DISCUSSIONS

Effects of bentonite on OMC and dry density of soil

The compaction curves of different mix ratios are shown in Fig.1. It is found that with the increase in percentage of bentonite the dry density decreases and corresponding optimum moisture content increases.

The variation of OMC and maximum dry density with varying bentonite percentages are shown in Fig.2. and Fig. 3. respectively. It is obtained that OMC increased from 12.2 to 14.5% and maximum dry density reduced from 1.974 to 1.87 g/cc when the percentage of bentonite increased from 0 to 8. Variation of dry density and OMC with different percentages of bentonite is given in Table 3.

Table 3. Variation of dry density & omc with different percentages of bentonite

Percentage of Bentonite	Maximum Dry Density (g/cc)	OMC (%)
0	1.974	12.2
2	1.965	12.5
4	1.948	12.8
6	1.929	13.0
7	1.921	13.2
8	1.866	14.5

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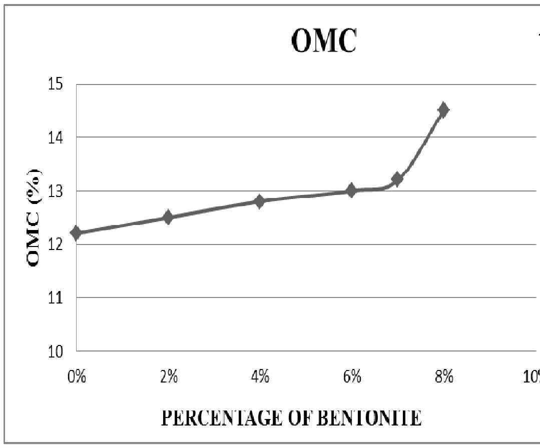

Fig.2. Variation of OMC with different percentages of Bentonite

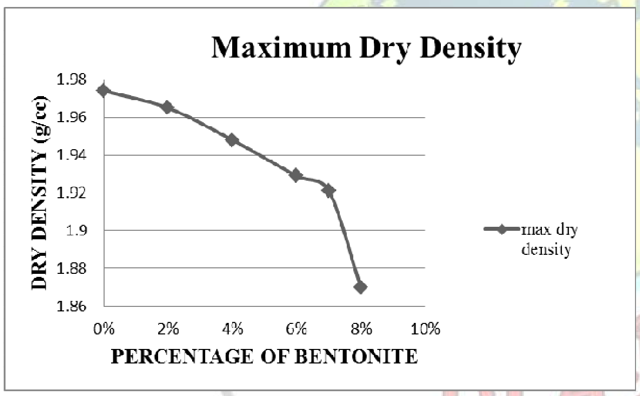

Fig.3. Variation of maximum dry density with different percentages of Bentonite

Effect of bentonite on hydraulic conductivity

Hydraulic conductivity of bentonite enhanced soil compacted to wet off optimum decreased with increasing bentonite content. Hydraulic conductivity of soil at different percentage of bentonite is shown in Table 4. The hydraulic conductivity obtained for 7% bentonite is 9.89 x 10^{-8} cm/s which is less than 1 x 10^{-7} cm/s.

Table 4. Variation of hydraulic conductivity

Bentonite in percentage	Hydraulic Conductivity (cm/s)
0	7.30 x 10^{-4}
2	2.23 x 10^{-6}
4	1.20 x 10^{-7}
6	9.89 x 10^{-7}
7	9.90 x 10^{-8}
8	1.79 x 10^{-6}

Check for design of characterisation of liner

The liquid limit and plastic limit of liner mix were obtained das 15% and 25% respectively resulting in a plasticity index of 25%. Since the value is between 12 % and 30 % the mix design can be adopted. The properties of liner are summarized in Table 5.

Table 5. Properties of Liner

Properties	Values
Liquid limit(%)	50.0
Plastic limit(%)	25.0
Plasticity Index	25.0
Maximum Dry Density	1.921 g/cc
OMC	13.2%
Permeability (cm/s)	9.9 x 10^{-8}

PRELIMINARY DESIGN OF LANDFILL

The preliminary design was done by using amended soil liner comprising of locally available soil with 7% of bentonite.

Basic Data
Location – Guruvayur
Waste generation – 8 tonnes per day
Design life – 16 years
Sub soil - Sandy soil are predominant
Current waste generation per year is 2920 tonness
Rate of increase of waste generation is 10%

Estimation of landfill capacity, landfill area

Total waste generation in n years is calculated by considering the current waste generation per year and proposed life of landfill. And it is obtained as 1.3 x 10^{5} tonnes. Total volume of waste in n years is depending on the total waste generation per year and density of waste. The obtained value is 1.529 x 10^{5} cu.m. Using total volume of waste, calculated the total volume of daily cover (on the basis of 15 cm soil cover on top and sides for lift height of 1.5-2m), total volume of liner and cover system (on the assumption of 1.5 m thick liner system and 1m thick cover system) and total volume of settlement (on the basis of settlement ratio and type of waste). And the values are 15290 cu.m, 38225 cu.m and 7645 cu.m. Using these values find out the capacity of landfill as 198770 cu.m.

The area for infrastructure and for landfill is 15 % and 85% of restricted area respectively. And it is 4158.14 m^2 and 23562.81 m^2. Average landfill height found out by using

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landfill capacity and restricted area available. The value is 8m. Then obtained the overall size of landfill as120 m x 200 m x 8m

Landfill Phases

It is considered as one phase is for one year and thus number of phases is 16. Volume of one phase obtained from landfill capacity and number of phases as 12423.13 m^3. Then Size of one phase can be calculated by using volume of one phase and landfill height. And the approximate plan area obtained is 60m x 25m. The volume of daily cell is found out from volume of one phase and number of daily cells (365). The plan area of one cell is 5m x 4m on the basis of 2m lift for each cell.

Liner & Leachate collection system

The liner system will comprise of following layers below the waste. And the thickness was fixed according to the recommendation of pollution control board.

(i) 0.2 m thick locally available soil is taken as protective layer
(ii) Drainage layer comprising of gravel or coarse sand with 0.3m thick
(iii) 1.5 mm thick HDPE geomembrane
(iv) 0.9 m thick land fill liner (here, the amended soil liner)

Amended soil liner design through laboratory testing.

locally available soil is mixed with Various percentages of bentonite in proportions of 2,4,6, and 8 % in laboratory and permeability determined. The minimum bentonite content determined for achieving permeability of less than 10^{-7} cm/s is 7% bentonite with locally available soil.

Leachate collection pipes:

Dia of HDPE pipe is fixed as 15 cm to reduce the effect of silting and to facilitate inspection and cleaning
Spacing of pipe 5m (based on length of daily cells)
Leachate holding tank= 20m x 10m x 3m

CONCLUSIONS

These are the conclusions made from the experimental studies.

- When the bentonite content increased from 0 to 8%, the maximum dry density decreased from 1.97 to 1.87 g/cc and optimum moisture content increased from 12.2 to 14.5%.
- With the addition of 7% bentonite the permeability of soil reduced to the range of 9.9 x 10^{-8} cm/s which satisfies the requirement of the permeability of liner.
- Preliminary design of landfill were done which having the total size 120m x 200m. And each phase contains 60m x 25 m size.

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