

## International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

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Vol. 6, Issue 11, November 2017

# Study on Liner Material Using Fly ash - Bentonite Mixture for Engineered Landfill

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**ABSTRACT:** Landfills must be highly engineered containment systems, designed to minimize the impact of soiled waste on the environment and human health. The design of a liner, in the case of economically developing countries, will vary depending on a number of factors, including the potential of the landfill polluting the land and water environments, the local hydrogeology and meteorology, and the availability of suitable materials and monetary resources..In this paper, Flyash is used as a basic material, the properties of this material are altered by adding bentonite to achieve the required properties of a competent material for landfill liners. Tests were conducted on fly ash with 8,12,16, and 20% of bentonite clay by weight. The main factor affecting the quality of compacted clay liners/covers is its permeability which should not be greater than  $1.0 \times 10^{-9}$  m/sec. The appropriate Bentonite - Red soil mix and the range of compaction parameters was determined that would give the required hydraulic conductivity, strength characteristics and minimum desiccation crack for their use as liner material.

**KEYWORDS:** Permeability, bentonite, fly ash, landfill liner.

### I. INTRODUCTION

Landfill is a land disposal site for waste. Preparation, management and control of the landfill must be of the highest standard to minimize the risks to human health and the environment. . Well-constructed and maintained landfills are safer than open dumping sites. Landfill liners are exposed to various types of physical, chemical and biological processes which affected by leachate produced from the decomposition of waste dumps. The aim is to avoid any hydraulic connection between the wastes and the surrounding environment, particularly groundwater. To ensure this, the important characteristics for compacted landfill liners are selection of materials, hydraulic conductivity, strength, compressibility and contaminant retention capacity.

Compacted clay liners are of low cost, large leachate attenuation capacity and resistance to damage. Natural clay is often fractured and cracked and due to non-availability of suitable soil at a site, it is necessary to mix imported clay materials with industrial process wastes to achieve a suitable material. Usually soil rich in clay minerals are used as compacted liner materials. But instead of clay, mixture of expansive soil such as bentonite with fly ash can be used as compacted liner materials for their low hydraulic conductivity which is required to be less than  $1.00 \times 10^{-7}$  cm/sec. Bentonite was mixed with fly ash in 8,12,16,and 20% by dry weight.

### II. LITERATURE REVIEW

Many researchers have investigated the potential of various materials to be used as liner material. Alam et al. [1] studied that 20% bentonite-fly ash mix can be safely used as liner material. Plain fly ash remained non-plastic until 20% bentonite was added to the mixture. Addition of bentonite enhanced the geotechnical properties of fly ash. Kananika nayak [2] concluded that as the bentonite content increased in the compacted mixture, the permeability decreased. 20% bentonite-fly ash mixture showed permeability less than  $1 \times 10^{-7}$  cm/sec, which fulfilled the criteria for landfill liner. Whereas for pond ash, it was achieved at 12% bentonite content in the mixture. Kumar et al. [3] concluded that in a

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bentonite-fly ash mixture the plasticity, hydraulic conductivity, swelling and shrinkage properties decreased and the dry unit weight and strength increased with the increase in fly ash content. Mollamahmutoglu et al. [4] mixed Catalagzi fly ash with bentonite at 5 to 30% by weight, to obtain less permeable liner material. With the increase in amount of bentonite, the MDD of the bentonite-fly ash mixtures increased at about same OMC, the permeability decreased, consolidated undrained shear strength parameters increased and the compressibility indices of the mixtures ranged from 0.009 to 0.019. It was concluded that a 20% bentonite-fly ash mixture proved to be a suitable liner material. Younus et al. [5] indicated that up to 70% fly ash content can be used to satisfy the requirements of compacted landfill liners.

In this paper, the work is divided into two stages. 1) Experimental work 2) Modelling. Experimental work is done to examine the properties of liner material. Engineering tests have been performed to infer properties of bentonite and fly ash for its suitability in specific purposes. After determined the range of compaction parameters that would give the required hydraulic conductivity, and strength characteristics for their use as liner material, model of landfill liner is made using 25 liter container and the suitability of material is examined.

Paper is organized as follows. Section III describes the Experimental work done and its results for finding an accurate mixture of fly ash and bentonite, feasible for being used as compacted clay liner, to reduce the migration of leachate to the ground water and reduced to reasonable amount and to investigate the physical and chemical properties of different liner material. Section IV shows the modeling process to check the use of liner material as landfill liner. Finally Section V presents conclusion.

### III. EXPERIMENTAL WORK AND METHODOLOGY OF MATERIALS COLLECTED

Bentonite used for the experimental purpose was brought from Sogyan Chemicals Corporation and fly ash was brought from Diggaru Railway Station. Bentonite was mixed with Fly ash in 8,12,16,20,24% by dry weight.

#### DETERMINATION OF MOISTURE CONTENT:

To determine the water content of the materials by oven drying method.

Table 1. Moisture Content of materials.

Sl No.	Description	Materials	
		Fly ash	Bentonite
1	Mass of the tray in gram, $M_1$	802	805
2	Mass of the tray + Soil in gram, $M_2$	1336	1106
3	Mass of the tray + Dry soil in gram, $M_3$	1279	1100
4	Mass of water, $M_4 = M_2 - M_3$	57	6
5	Mass of dry sand, $M_5 = M_3 - M_1$	477	295
6	Moisture Content, $\frac{M_4}{M_5} \times 100\%$	11.95	2.03

#### DETERMINATION OF SPECIFIC GRAVITY:

The specific gravity of fly ash and bentonite were found out according to IS: 2720 (part- III, section-1)1980 by using pycnometer. In case of bentonite kerosene was used as it is non-polar in nature and so kerosene will not react with bentonite.

Table 2. Specific Gravity of Materials.

Sl. No	Materials	$M_1$ (gm)	$M_2$ (gm)	$M_3$ (gm)	$M_4$ (gm)	Specific Gravity
1	Red soil	70	80	130	126	1.66
2	Flyash	70	80	165	160	2.0

Where,

$M_1$  = Mass of an empty Pycnometer in gram

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$M_2$  = Mass of an Pycnometer + Sample in gram  
 $M_3$  = Mass of an Pycnometer + Sample + Water in gram  
 $M_4$  = Mass of an Pycnometer + Water in gram  
 Specific Gravity =  $\frac{M_2 - M_1}{(M_2 - M_1) - (M_3 - M_4)}$

### SEDIMENTATION ANALYSIS:

A sample to be tested is placed without drying in a 200cc measuring cylinder, so that the sample is up to the 100cc mark. Add clean water up to 150cc mark. Dissolve one spoon of common salt in half liter of water thoroughly and add this to the measuring cylinder. The mixture is then shaken vigorously, the last few shakes being in sidewise direction. Allow the solids to settle down for a period of three hours.

First the sand and then silt and clay over it. The height of the fine silt visible as settled layer above the sand is expressed as a percentage of the height of the sand below the silt content.

Table 3. Sedimentation analysis.

Materials	V <sub>d</sub> (ml)	V <sub>k</sub> (ml)	FSI(%)
Flyash	10	10	0
Bentonite	96	5	540

### FREE SWELL INDEX:

To determine the free swell index of soil as per IS: 2720 (Part XL) – 1977, the apparatus used are IS Sieve of size 425µ, Oven, Balance, with an accuracy of 0.01g, Graduated glass cylinder- 2 nos., each of 100ml capacity, and Kerosene.

Take two specimens of 10g each of sample passing through 425µm IS Sieve and oven-dry. Pour each specimen into a graduated glass cylinder of 100ml capacity; now pour distilled water in one and kerosene oil in the other cylinder up to 100ml mark. Remove entrapped air by gently shaking or stirring with a glass rod, allow the suspension to attain the state of equilibrium (for not less than 24hours). Final volume of sample in each of the cylinder should be read out.

Free swell index =  $[V_d - V_k] / V_k \times 100\%$

where,

V<sub>d</sub> = volume of soil specimen read from the graduated cylinder containing distilled water.

V<sub>k</sub> = volume of soil specimen read from the graduated cylinder containing kerosene.

Table Error! No text of specified style in document.. DFS of materials

Materials	V <sub>d</sub> (ml)	V <sub>k</sub> (ml)	FSI(%)
Flyash	10	10	0
Bentonite	96	5	540

Table Error! No text of specified style in document.. DFS of fly ash – bentonite mixture

Materials	V <sub>d</sub> (ml)	V <sub>k</sub> (ml)	FSI(%)
Flyash + 8% bentonite	29	15	93.33
Flyash + 12% bentonite	38	18	111.11
Flyash + 16% bentonite	44	16	175
Flyash + 20% bentonite	47	15	213

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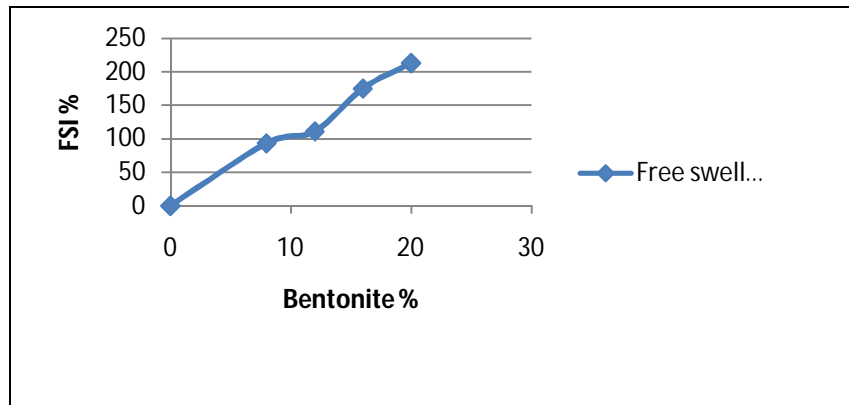


Figure 1:Free swell index of fly ash and bentonite mixtures.

## 5. ATTERBERG LIMITS:

### a) Determination of Plastic Limit:

Plastic limit represents the water content at which a soil would just begin to crumble when rolled into a thread of approximately 3 mm diameter, this test were conducted to determine the plastic limit as per IS 2720(part V)-1985.

Table 6. Plastic limit of fly ash – bentonite mixture

SI no	Mate-rials	Mass of container (M <sub>1</sub> ) in gm	Mass of container+wet thread sample (M <sub>2</sub> )in gm	Mass of container + dry thread sample (M <sub>3</sub> ) in gm	Plastic limit
1	Flyash	18	31	29	Non-plastic
2	Bentonite	22	26.5	24	125
3	Flyash + 8% bentonite	18	32	30	Non-Plastic
4	Flyash + 12% bentonite	18	28	26	25
5	Flyash + 16% bentonite	18	26	25	14.28
6	Flyash + 20% bentonite	18	25	23	41.43

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## b) Determination of liquid limit:

Test for liquid limit was conducted according to IS 2720 (part V)-1985 in the Cassagrande's liquid limit device.

Table 7. Observation of Liquid limit of fly ash- bentonite mixtures

Sl no.	Materials	Liquid limit (%)
1	Fly ash	34
2	Bentonite	355
3	Flyash + 8% bentonite	38
4	Flyash + 12% bentonite	49
5	Flyash + 16% bentonite	54
6	Flyash + 20% bentonite	61

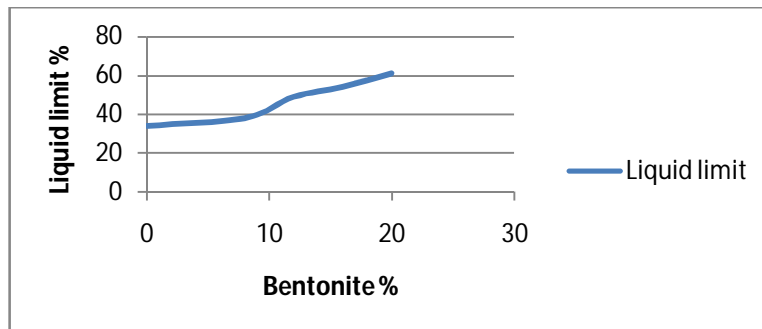


Figure 1. Liquid limit with increase in % of bentonite in fly ash

## c) Determination of Plasticity Index

Plasticity Index (Ip) is obtained by calculating the difference between Liquid Limit and Plastic Limit i.e.,  $PI = (LL-PL)$ .

Table 8. Plasticity index of fly ash- bentonite mixtures

Sl no	Materials	Liquid limit	Plastic limit	Plasticity index
1	Flyash	34	Non-plastic	Non-plastic
2	Bentonite	355	125	230
3	Flyash + 8% bentonite	38	16.66	21.34 (Non-plastic)
4	Flyash + 12% bentonite	49	25	24
5	Flyash + 16% bentonite	54	32	22
6	Flyash + 20% bentonite	61	41.43	19.57

## 6. Standard Proctor Test:

To determine the dry density and moisture content relation of soil and to find OMC and MDD from the relationship, standard proctor test is done.

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Table 9. Compaction Characteristics of fly ash – bentonite mixture.

Materials	MDD (g/cc)	OMC (%)
Fly ash + 0% bentonite	1.23	26
Fly ash + 8% bentonite	1.41	23
Fly ash + 12% bentonite	1.44	22.5
Fly ash + 16% bentonite	1.47	21.9
Fly ash + 20% bentonite	1.52	21

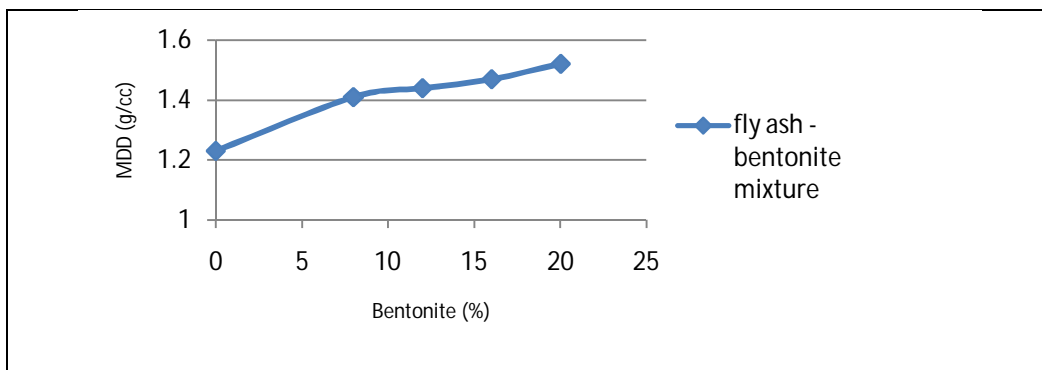


Figure 2. Variation of MDD of fly ash -bentonite mixtures

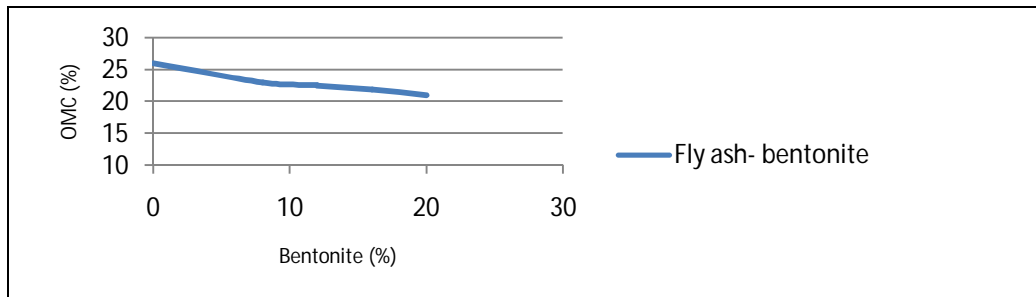


Figure 4. Variation of OMC of fly ash – bentonite mixtures.

### 7. DETERMINATION OF PERMEABILITY:

The falling head permeability test is a common laboratory testing method used to determine the permeability of fine grained soils with intermediate and low permeability such as silts and clays. This testing method can be applied to an undisturbed sample.

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**Table 10. Permeability of fly ash - bentonite mixtures**

SN	Materials	Coefficient of Permeability (cm/sec)
1	Flyash+ 0% bentonite	$142.3 \times 10^{-7}$
2	Flyash + 8% bentonite	$1.92 \times 10^{-7}$
3	Flyash + 12% bentonite	$1.23 \times 10^{-7}$
4	Flyash + 16% bentonite	$0.8 \times 10^{-7}$
5	Flyash + 20% bentonite	$0.26 \times 10^{-7}$

## 8. FREE SWELL INDEX:

To determine the free swell index of soil as per IS: 2720 (Part XL) – 1977, the apparatus used are IS Sieve of size 425 $\mu$ , Oven, Balance, with an accuracy of 0.01g, Graduated glass cylinder- 2 nos., each of 100ml capacity, and Kerosene. Take two specimens of 10g each of sample passing through 425 $\mu$ m IS Sieve and oven-dry. Pour each specimen into a graduated glass cylinder of 100ml capacity, now pour distilled water in one and kerosene oil in the other cylinder upto 100ml mark. Remove entrapped air by gently shaking or stirring with a glass rod, allow the suspension to attain the state of equilibrium (for not less than 24hours). Final volume of sample in each of the cylinder should be read out.

Free swell index =  $[V_d - V_k] / V_k \times 100\%$

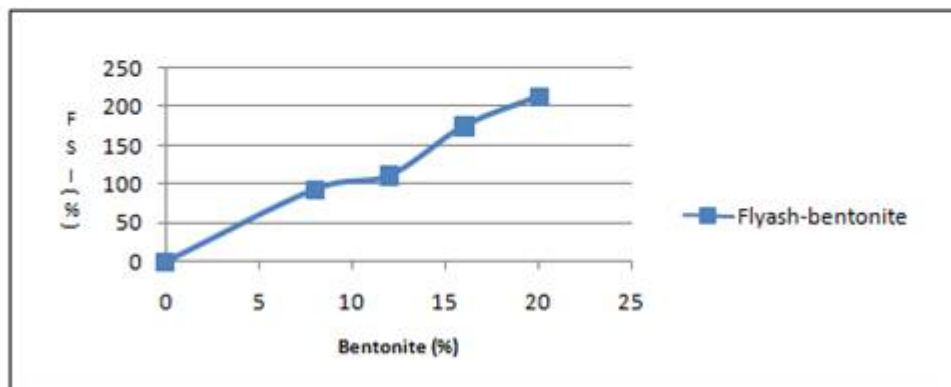
where,

$V_d$  = volume of soil specimen read from the graduated cylinder containing distilled water.

$V_k$  = volume of soil specimen read from the graduated cylinder containing kerosene.

**Table 11. DFS of Flyash – bentonite mixture**

Materials	$V_d$ (ml)	$V_k$ (ml)	FSI(%)
Flyash + 8% bentonite	29	15	93.33
Flyash + 12% bentonite	38	18	111.11
Flyash + 16% bentonite	44	16	175
Flyash + 20% bentonite	47	15	213



**Figure 5. Free Swell Index with increased in bentonite**



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## IV. MODELLING OF LANDFILL LINER

### 1. MODEL OF LANDFILL LINER USING FLYASH – BENTONITE MIXTURE.

A model of landfill is prepared using 25 liter container. At bottom make a hole and place plastic bag to collect the leachate.  $\frac{1}{3}^{\text{rd}}$  of the container is filled with compacted Flyash and 16% bentonite mixture liner at OMC. Then household waste are placed on the liner and covered with soil. Two layers of waste are placed on the liner, watered it at each layer. Sprinkle water everyday and after some days measure the amount of laechate passes through liner. The stepwise process of engineered landfill model is shown in figures given below.



Figure 6: (a) 25 liter container for landfill model (b)  $\frac{1}{3}^{\text{rd}}$  of container filled with flyash – 16% flyash mixture (c) Household waste on the layer of Flyash- 16% bentonite mixture. (d) Compacted layer of Flyash – 16% bentonite mixture on household waste, (e) Landfill liner after 8 days of rain. (f) Leachate collected after 13 days.

## V. CONCLUSION

Based on the experiments done on fly ash with bentonite for liner material the test results is observed that when the percentage of bentonite increases, consistency properties such as liquid limit, plastic limit and plasticity index are



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increasing. The Differential Free Swell of the mixture increased with the addition of bentonite, resulting as a better sealant. At addition of 16% bentonite in fly ash, the material has  $0.8 \times 10^{-7}$  cm/sec which is less than  $1 \times 10^{-7}$  cm/sec (recommended permeability of liner). Hydraulic conductivity of fly ash- bentonite mixture decreased linearly with increased amount of bentonite. 16% - 20% increase in bentonite content in fly ash, induced plasticity which led to better bonding between particles upon compaction and had the required hydraulic conductivity and strength properties to be used as a liner material. Hence fly ash -bentonite mixture is suitable as liner material with 16% -20% bentonite. Based on model of engineered landfill it is observed that fly ash as liner material alone cannot be good material for engineered landfill whereas a compacted mixture of bentonite with fly ash with the percent of bentonite in the mixture between 16-20 % is good for liner material for engineered landfill.

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