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A Study on Geotechnical Properties of Flyash Mixed with Bentonite

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Abstract—*In this study commercially available bentonite was mixed with locally available nearby thermal plants fly ash in different proportion (i.e. 0%,2%,4%,8%,12% & 20%). Fly ash are non plastic & possess very low shrinkage. With the addition of bentonite in the mixture, the plasticity is expected to increase & the fly ash is expected to reduce the swelling & shrinkage, preventing formation of any cracks. Due to its swelling properties, bentonite in the mixture is expected to act as a self sealing, low permeability hydraulic barrier. To determine the viability of fly ash –bentonite mixture as a liner material, the laboratory tests were conducted to obtain the various geotechnical parameters such as plastic limit,liquid limit, plasticity, shrinkage limit, differential free swell index & linear shrinkage. It was found that a mixture of bentonite with fly ash with the percent of bentonite in the mixture between 12-20%, induced plasticity in the fly ash – bentonite mixture which led to better bonding between particles upon compaction.*

Keywords*: Fly Ash, Bentonite, Liner Material, Plasticity.*

1. INTRODUCTION

Liners in a waste contaminant site play an important role to retard migration of leachate & its toxic constituents into the groundwater or nearby aquifer. A typical landfill liner should have low permeability, resistance against shearing, minimize pollutant migration, should withstand erosion, low swelling & shrinkage. Locally available compacted clays are usually used as liner material due to their high unconfined strength & low hydraulic conductivity. The availability of local soil, satisfying the engineering properties of a liner material for waste contaminant site is deceasing day by day. Due to this, the recent research is focused on finding the mechanical & environmental suitability of the waste materials & byproducts such as fly ash, sand-bentonite, rubber-bentonite, red mud & lime-fly ash- PVC as liner material for waste contaminant site. In India, presently 138 numbers of coal based thermal power plants are producing approximately 163 million tone of fly ash/year & approximately 61% of the total fly ash/is reused by the different industries. The total fly ash generation of the country will be approximately 300-400 million tone/year by 2017 & about 4000 hectare of land is required to store this huge quantity of fly ash. Due to the characterstics of fine particles & trace metal content, disposal of huge quantities of fly ash has caused serious space & environmental problem including soil contamination, groundwater pollution & suspension of fine particles in air. To reduce the environmental & space problem, it is essential to find the potential applications of fly ash in bulk quantity. This study on fly ash is focused to reduce its storage problem by finding its mechanical & environmental suitability as bottom liner in waste contaminant site. Use of fly ash amending with suitable matrices helps in conserving the natural resources as well as solves the disposal & environmental problems associated with it. In the present study suitability of fly ash amended with bentonite has been studied for the bottom liner in waste contaminant site.fly ash collected from a power plant in India has been taken for present study. Atterberg limit i.e. plastic limit, liquid limit, plasticity, shrinkage limit, linear shrinkage & swell tests were performed on fly ash- bentonite mixture.

2. MATERIALS

2.1. Fly Ash

Sample of low lime fly ash used for the experimental purpose was brought from NTPC,Badarpur plant.Fly ash is micron-sized, glassy powder residue as a result of coal combustion in power plants. It was oven dried at a temperature of 105-110°C, prior to the tests. The various properties were obtained & showcased in table 1. According to ASTM C618 (2008), These fly ash have been classified as class F type.

2.2. Bentonite

Commercially available Na-bentonite was used for the present study. It consists of 96.59% fines in which clay is predominant (60%). Physical properties of the bentonite are also given in table 1. As per ASTM D2487, the bentonite is classified as clay with high compressibility (CH).

Table 1: Physical properties of fly ash & bentonite

Physical Parameter	Fly ash	Bentonite
Color	Grey	Cream
Shape	Rounded/ Subrounded	Platy

Uniformity Coefficient	5.71	-
Coefficient Curvature	1.27	-
Specific Gravity	2.33	2.89
Plasticity Index (%)	Non plastic	236
IS Classification	-	CH
Liquid Limit(%)	51.5%	301%
Plastic Limit (%)	Non plastic	65%
Shrinkage Limit (%)	41.5%	5%
DFS (%)	-	556%

3. DETERMINATION OF GEOTECHNICAL PROPERTIES

Experimental Procedure

The fly ash sample from plant was oven dried at approximately 105-110°C before preparing the mixture of fly ash- bentonite composite sample for present study. In the composite sample for present, quantity of bentonite was carried varied to see its effect on the properties of composite sample. Bentonite was added in the proportion of dry weight of the fly ash & the the materials were blended vigorously in dry state to have a homogeneous mixture of different material in composite sample. Atterberg limit test, plasticity, linear shrinkage & differential free swell test were conducted to determine the geotechnical properties of the composite sample.Table 2 gives the composition of the different types of composite sample on weight basis that were tested to find the suitability as bottom liner materials.

Table 2: Composition of composite samples

Composition	Materials	
	FA (%)	BN (%)
FA-BN	100	0,2,4,8,12,20

Where FA- Fly Ash sample

BN- Bentonite sample

3.1. Atterberg's Limit Test

The fly ash & bentonite was oven dried for 24 hours & run through 425micron sieve. Fly ash was mixed with the relevant quantities of bentonite (i.e. 0,4,8,12,20%). The Atterberg limit test for all fly ash- bentonite mixtures were conducted as per following IS code. The Atterberg limit reported was the average of three trials.

3.1.1. Liquid Limit

The liquid limit of fly ash –bentonite mixtures specimen was determined in the laboratory with the help of cone penetrometer as per IS:2720- V.

Table 3: Liquid limit of bentonite-flyash mixtures

Sample Sets	LL(%)
0% bentonite-fly ash mixture	51.5
2% bentonite-fly ash mixture	52.5
4% bentonite-fly ash mixture	53
8% bentonite-fly ash mixture	55
12% bentonite-fly ash mixture	64
20% bentonite-fly ash mixture	72

3.1.2. Plastic Limit

The plastic limit was determined by roll thread method as per IS:2720 (Part V)-1986.The plastic limit of the composite mix samples were determined by rolling the samples to a thread of 3mm diameter. When the sample began to crumble during rolling the corresponding water content was taken as plastic limit of the composite mix sample.

Table 4: Plastic limit of bentonite-fly ash mixtures

Sample Sets	PL(%)
0% bentonite-fly ash mixture	Non-plastic
2% bentonite-fly ash mixture	Non-plastic
4% bentonite-fly ash mixture	Non-plastic
8% bentonite-fly ash mixture	Non-plastic
12% bentonite-fly ash mixture	44
20% bentonite-fly ash mixture	45

3.1.3. Shrinkage Limit

Shrinkage limit was determined as per IS- 2720 (Part VI) 1972 with the help of shrinkage dish. The sample preparation involved taking about 30 g of dry sample passing through 425 micron IS sieve and thoroughly mixing with distilled water to form a paste, which was left standing for 24 hours. The consistency of the paste was workable enough to place it in the shrinkage dish without entrapping air bubbles. Since bentonite was being tested, the water added was about 5%-10% more than the liquid limit. The specimen were tested and the values of shrinkage limit obtained are presented in the tables 5.

Table 5: Shrinkage limit of bentonite-fly ash mixtures

Sample Sets	SL(%)
0% bentonite-fly ash mixture	41.5
2% bentonite-fly ash mixture	41
4% bentonite-fly ash mixture	40
8% bentonite-fly ash mixture	39
12% bentonite-fly ash mixture	38
20% bentonite-fly ash mixture	36.5

3.2. Plasticity Index

Plasticity Index (Ip) is obtained by calculating the difference between Liquid Limit and Plastic Limit. The values for different samples are presented in tables 3 and 4.

Table 6: Plasticity Index of bentonite-fly ash mixtures

Sample Sets	PI (%)
0% bentonite-fly ash mixture	Non-plastic
2% bentonite-fly ash mixture	Non-plastic
4% bentonite-fly ash mixture	Non-plastic
8% bentonite-fly ash mixture	Non-plastic
12% bentonite-fly ash mixture	20
20% bentonite-fly ash mixture	27

3.3. DFS (Differential Free Swell) Test

Differential Free Swell was determined according to IS 2720 (Part XI)-1977. For the test two oven dried sample passing through 425 micron IS sieve weighing 20 g each were placed separately in two 100 ml graduated cylinder. Distilled water was used to fill one cylinder and kerosene was used to fill another up to the 100 ml mark. In case of bentonite, 10 gm of sample were taken for the test. The final reading of volume of soil was taken after 24 hours to calculate free swell index. The percent differential free swell was calculated as :

$$DFS (\%) = [(V_d – V_k)/ V_k] \times 100$$

Where,

Vd = The volume of sample noted from the graduated cylinder containing distilled water .

Vk = The volume of sample noted from graduated cylinder containing kerosene.

The values of DFS for different specimen are listed in the tables 7 and 8.

Table 7: DFS of materials

Material	DFS(%)
Fly ash	-
Bentonite	556

Table 8. DFS of bentonite-fly ash mixtures

Sample Sets	DFS(%)
0% bentonite-fly ash mixture	-
2% bentonite-fly ash mixture	-
4% bentonite-fly ash mixture	31.5
8% bentonite-fly ash mixture	86
12% bentonite-fly ash mixture	137
20% bentonite-fly ash mixture	178

3.4. Linear Shrinkage Test

Tests for linear shrinkage were conducted in moulds specified by IS 12979,1990. Paste samples were prepared by mixing 150 gm of material passing 425 micron IS sieve with water, approximately 2% above the liquid limit & left to stand for 24 hours. The paste was placed in the shrinkage mould & then gently jarred to remove any air pockets in the paste. It was leveled off along the top of the mould with the palette knife. The mould was placed so that the paste could air dry slowly, until the soil had shrunk away from the walls of the mould. Drying of the mould first started at a temperature of 60 to 65°C until shrinkage had largely ceased and then at 105 to 110°C to complete the drying. After cooling of mould containing dried soil, the mean length of soil bar in the mould was measured by vernier caliper, if the specimen had curved during drying, the measurement should be made along the mean arc. The linear shrinkage of the soil was calculated from the following formula:

$$LSI (\%) = [l - (L_{avg}/ L_o)] \times 100$$

Where,

Lavg = Average length of soil (mm)

Lo = Original length of brass mould (mm)

The values obtained for the materials & the fly ash-bentonite mixtures are listed in the tables 9 & 10.

Table 9: Linear Shrinkage of materials

Material	LS(%)
Fly ash	1.06
Bentonite	44.65

Table 10: Linear Shrinkage of bentonite-fly ash mixtures

Sample Sets	LS(%)
0% bentonite-fly ash mixture	1.06
2% bentonite-fly ash mixture	2.05
4% bentonite-fly ash mixture	3.04
8% bentonite-fly ash mixture	3.83
12% bentonite-fly ash mixture	5.55
20% bentonite-fly ash mixture	7.93

4. RESULTS & DISCUSSIONS

4.1.Effect of Bentonite on Atterberg's Limits

4.1.1.Liquid Limit,Plastic Limit,Shrinkage Limit & Plasticity Index

Atterberg limits of the composite mix samples were determined as per IS:2720-1986 (Part V). Liquid limit of both the fly ash - bentonite mixtures were determined by cone penetration method. The plastic limit of the composite mix samples were determined by rolling the samples to a thread of 3mm diameter. When the sample began to crumble during rolling, the corresponding water content was taken as plastic limit of the composite mix sample. Fig.1 & 2 shows the variation in Atterberg limits of the fly ash sample with percentage of bentonite. Liquid limit increases with increase in bentonite content of the FA-BN samples.The composite samples changes from non-plastic to plastic soil group & exhibit plastic limit of more than 20% & 10% resspectively, when added with bentonite. With increase in bentonite content, plasticity index of the samples increases due to decrease in plastic limit & hence plasticity increases. Bentonite being high plastic clay (CH) imparts plasticity to FA-BN composite sample.

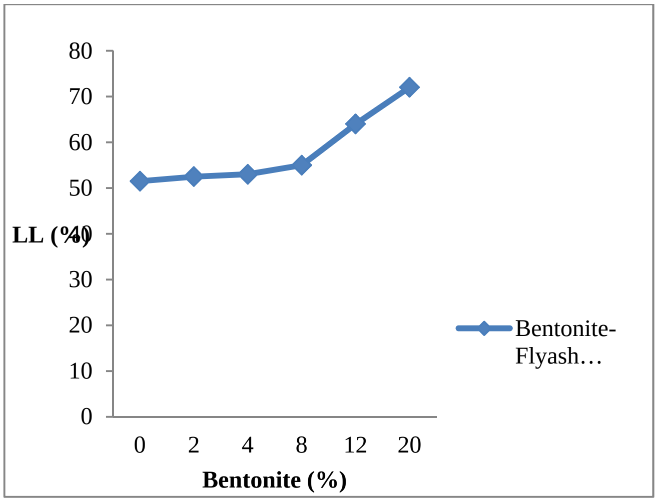

Fig. 1: Variation of liquid limit with bentonite content

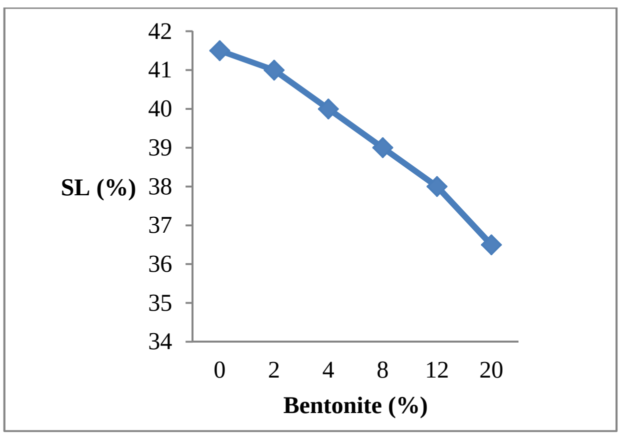

Fig. 2: Variation of shrinkage limit with bentonite content

4.2. Effect of Bentonite on DFS Test

The swelling of bentonite mix soil is a major concern & for the present investigation, DFS test of sample of flyash-bentonite was determined.Fig.3 shows the variation of DFS of the fly ash samples with percentage of bentonite.

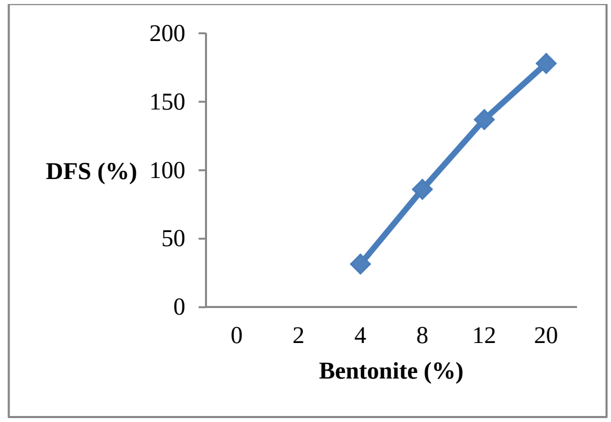

Fig. 3: Variation of DFS with bentonite content

Fig.3 shows that with addition of bentonite,plasticity index of the flyash- bentonite samples increases resulting in increase in DFS of the sample.

4.3. Effect of Bentonite on Linear Shrinkage Index

In case of bentonite, formation of shrinkage crack is the major issue to be tackled while considering it for waste containment liner. The bentonite used for the project work had a high linear shrinkage index of 44.65% and showed prominent desiccation cracks. When mixed with fly ash, there was a remarkable reduction in the shrinkage of the mixture. The linear shrinkage Index (LSI) remained within 10% for both the fly ash-bentonite mixtures. The variation is presented in the Fig. 4.

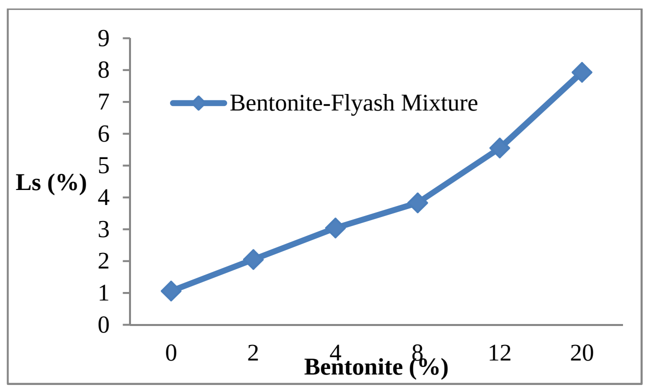

Fig. 4: Variation of LSI with bentonite content

5. CONCLUSIONS

Present study investigated the feasibility of using fly ash stabilized with bentonite as landfill liner material of a waste contaminant site. A detailed study on effect of bentonite on fly ash- bentonite composite sample was done through laboratory investigations. Fly ash having different grain size distribution were used for the present study. Na-based bentonite was mixed with samples of fly ash in different proportions & suitability of composite sample as liner material has been investigated. From the present study following conclusions can be drawn.

(i) Bentonite in suitable quantity blended with fly ash may be used as a bottom liner of a landfill site.

(ii) Fly ash having finer grain size distribution is more suitable as liner material as it attains the benchmark hydraulic conductivity value with less amount of bentonite.

(iii) An increase in liquid limit & subsequent decrease in plastic limit are observed for both the fly ash samples.Bentonite induces plasticity in the fly ash- bentonite composite sample & plasticity index increases with increasing the percentage of bentonite.Plasticity of the fly ash- bentonite composite sample makes it easy to handle as construction material also.

(iv) An increase in bentonite content of 12%-20% induced plasticity in the fly ash-bentonite mixture which led to better bonding between particles upon compaction.

(v) The differential free swell of the mixture increased with the addition of bentonite, resulting as a better sealant.

(vi) There was a variation in shrinkage limit & linear shrinkage in the fly ash-bentonite mixture with the addition of bentonite, without formation of prominent shrinkage cracks.In case of fly ash-bentonite mixture the variation of shrinkage limit fell in the range of 41%-36,5%.

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