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Evaluating the Utility of Fly Ash for Waste Containment Application

EVALUATING THE UTILITY OF FLY ASH FOR WASTE CONTAINMENT APPLICATION

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Abstract: *In many countries regulations require all hazardous waste disposal facilities to be lined with suitable impermeable barriers to protect against contamination. In this study, a series of laboratory tests on bentonite added fly ash were conducted. The aim of the tests is to evaluate the feasibility of utilizing fly ash, and bentonite as a low permeable barrier, at the same time satisfying compressibility and strength criteria. Type C fly ash was obtained from "Farakka" thermal power plant located in West Bengal. To evaluate the properties of bentonite added fly ash, hydraulic conductivity, unconfined compression, one dimensional consolidation tests were performed. The overall evaluations of results indicates that fly ash investigated in this study has a good potential for mass applications in geoenvironmental projects such as waste containment liners, there by utilizing a waste product for cleaner environment.*

Keywords: *Bentonite, Compressibility, Strength; Fly ash, Hydraulic conductivity, Liner, Laboratory study.*

INTRODUCTION

One of the major environmental problems is safe disposal of solid waste material such as municipal waste, industrial waste, hazardous waste and low level radioactive waste (Hanson 1989). While countries are industrialized, enormous amounts of solid waste are generated. These waste materials are generally placed in landfills. Landfills are usually lined with an impermeable material to prevent contamination of the surrounding soil and underlying groundwater by waste leachate. Thus, the most significant factor affecting its performance is hydraulic conductivity (Daniel 1987, 1990). Compacted clay liners are widely used in solid waste landfills due to their cost effectiveness and large capacity of contaminant attenuation. In the absence of impermeable natural soils, compacted mixtures of bentonite and sand have found wide applications as contaminant barriers (Daniel and Wu, 1993). It is to be noted that, in case, these materials are not locally available the cost of the project increases manifold due to its import from elsewhere. Also, sand has become an expensive construction material due to its limited availability. Therefore, it is of paramount importance to research new materials for landfill liner construction without compromising on the primary objective of efficient waste containment. The improved efficiency refers to better performance in terms of containment or sustainability of containment (Shackelford, 2005).

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In this study, effort has been made to evaluate the usefulness of fly ash for liner construction and there by substituting sand. Fly ash is a waste produced from coal-fired power generating stations and is readily available and need to be safely disposed. A large amount of the fly ash produced is disposed in monofills (Nhan et al., 1996). The disposal of fly ash is becoming expensive each year due to the large area of land needed for its disposal. One of the amicable solutions to the problem is reuse of fly ash for some meaningful applications. The pozzolanic and self hardening properties of fly ash have naturally made it a very attractive material for use in a variety of construction applications such as fills, concrete, pavements, grouts etc. (Nhan et al., 1996). However, the utility of fly ash for geoenvironmental projects as landfill liner material has not been fully explored. With this in view, the present study purports to examine the suitability of fly ash as a landfill liner material. The major objective of this study is to maximise the use of fly ash for the said application. Therefore, different fly ash-bentonite mixes were subjected to hydraulic conductivity, unconfined compressive strength and compressibility determination. Based on these results, the desirable fly ash-bentonite mix ratio has been identified for its application in waste containment systems.

EXPERIMENTAL INVESTIGATION

The fly ash used in this present study is an industrial by-product obtained from the "Farakka" thermal power plant located in West Bengal. The specific gravity, particle size analyses, consistency limits, compaction characteristics and were determined by following the methods reported in the literature (ASTM D-854, ASTM D-422, ASTM D-1140, ASTM D-4318, and ASTM D-698). The summary of these characterizations is listed in Table 1. The grain size distribution curve indicates that the fly ash is a predominantly uniform silt sized material. The different fly ash-bentonite mixes used in this study are listed as shown in Table
2. The weight percentage used for the mixes are also shown.

Table 1: Properties of the materials used

Test	values
Properties of Fly ash	
Specific gravity	2.08
Particle size (%)	
Gravel	0
Fine sand	24.6
Clay + Silt	74.9
Properties of Bentonite	
Specific gravity	2.57
Liquid limit (%)	223.87
Plastic limit (%)	43.3
Plasticity index (%)	180.57

Table 2: Fly ash-bentonite mixes used in this study

Designation	**Bentonite (%)**	**Fly ash (%)**
B0F100	0	100
B30F70	30	70
B50F50	50	50
B60F40	60	40
B80F20	80	20
B100F0	100	0

These mixes were subjected to the basic characterization as mentioned above as well as geotechnical characterization such as compaction, hydraulic conductivity, unconfined compressive strength, and one-dimensional consolidation (ASTM D698; ASTM D5084; ASTM D2166; ASTM D243). It must be noted that geotechnical characteristics has been obtained corresponding to optimal moisture content (w_{OMC}) and maximum dry density (γ_{dmax}) state of compaction. The values of optimum compaction parameters along with the basic characteristics are listed in Table 3. It can be noted that w_{OMC} and γ_{dmax} increase with an increase in bentonite percentage.

Table 3: Physical and compaction characteristics of the fly ash-bentonite mixes

Mix	G	Liquid limit (%)	Plastic limit (%)	γ_{dmax} (kN/m^3)	w_{OMC} (%)
B0F100	2.071	NP	NP	13.53	20.29
B30F70	2.193	91.02	22.80	14.52	19.66
B50F50	2.272	126.78	28.40	15.18	21.00
B60F40	2.336	151.19	30.87	15.24	22.04
B80F20	2.414	180.13	38.24	15.29	24.22
B100F0	2.570	223.88	43.30	15.39	29.66

RESULTS AND DISCUSSION

In addition to regulated parameters in landfill design such as hydraulic conductivity, density and water content, other non regulated parameters such as compressibility and shear strength has also been taken into consideration for evaluating fly ash utility as landfill liners. The results of unconfined compressive strength (UCS), compressibility index (Cc) and hydraulic conductivity (k) for different fly ash-bentonite mixes corresponding to optimum standard Proctor compaction states are presented in Table 4. It can be noted that the geotechnical characteristics varies over a wide range for the mixes investigated in this study.

Table 4: Geotechnical characteristics corresponding to optimum compaction condition

Mix	UCS (kPa)	Cc	k (cm/sec)
B0F100	8.61	0.11	3.55*E-4
B30F70	51.31	0.17	3.75*E -8
B50F50	82.90	0.28	2.04*E -10
B60F40	85.23	0.33	9.32*E -11
B80F20	66.82	0.38	6.24*E -12
B100F0	34.90	0.45	5.65*E -14

Hydraulic conductivity is one of the vital parameters governing the contaminant migration. The suitability of a soil or admixture is ensured only if the compacted layer of a particular soil achieve hydraulic conductivity less than or equal to 10^{-7} cm/s (Daniel 1993). Therefore, hydraulic conductivity is plotted as a function of fly ash percentage as depicted in Fig.1. Keeping in view, the major objective of this study to maximise the use of fly ash, it can be noted from Fig. 1 that the maximum percentage of fly ash meeting hydraulic conductivity criterion is 74. It is clear from this study that any higher percentage of the fly ash considered in this study would violate the hydraulic conductivity criterion.

Further, the UCS has been plotted as a function of fly ash content as depicted in Fig. 2. Compacted soils used for waste containment liners must have adequate strength for stability. Reviewing the literature, it is noted that there is no strict guidelines on the requirement of strength. Some researchers have arbitrarily fixed the value of UCS as 200 kPa (Daniel 1993). From Fig. 2, it can be noted that the maximum strength is obtained for B60F40 mix followed by B50F50. However, there is not much appreciable difference between the UCS of these two mixes. Keeping in view the objective of the study, B50F50 becomes optimal mix satisfying hydraulic conductivity and UCS criteria.

Apart from the above two criteria, it is also important to ensure the compressibility of liner material. The results of Cc tabulated in Table 3, is plotted with respect to fly ash percentage. As expected, it can be noted that Cc decreases with an increase in fly ash percentage. It must be noted that there is no well defined criterion available in the literature for evaluating the liner material based on compressibility. Based on the previous discussion, it is noted that B50F50 becomes optimal mix for which the compressibility is 0.28. This compressibility value cannot be considered to be very high for the load due to waste acting on the compacted liner material. Therefore, based on the present investigation, fly ash: bentonite mix equal to 50:50 is proposed for liner construction application. However, further investigations are required to improve the UCS of the mix so that B30F70 mix can be utilized for the said purpose, thereby maximising the utilization of fly ash.

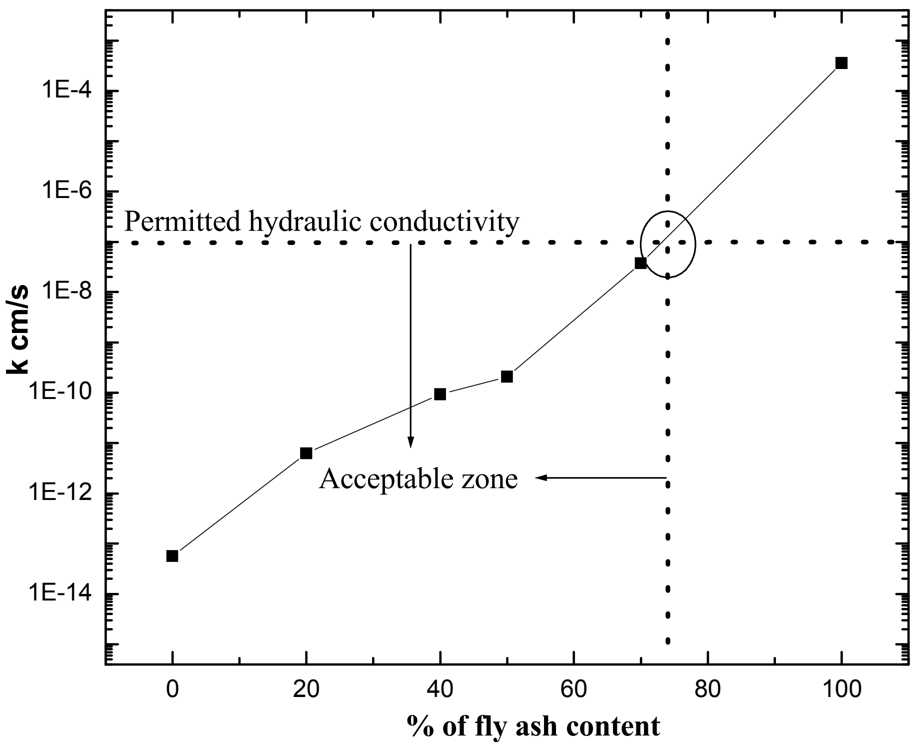

Figure 1: Results of hydraulic conductivity tests

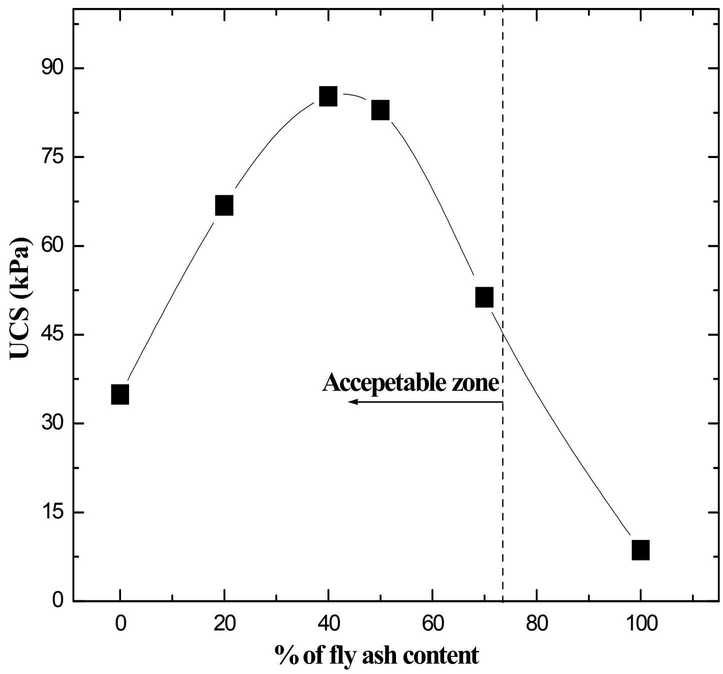

Figure 2: Variation of UCS with fly ash content

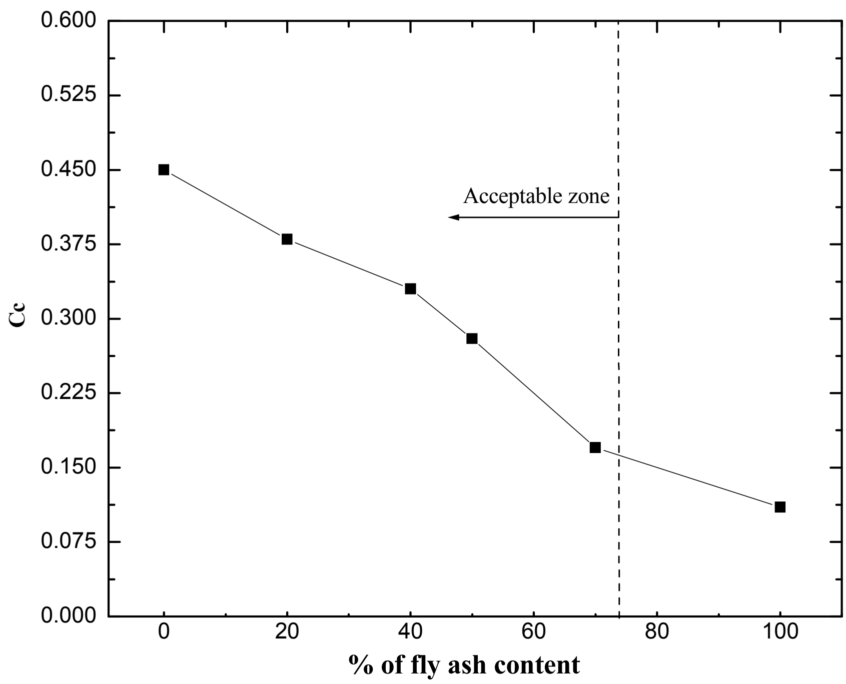

Figure 3: Variation of Cc with fly ash content

CONCLUDING REMARKS:

In this study, a series of laboratory tests on bentonite added fly ash were conducted. The aim of the tests is to evaluate the feasibility of utilizing fly ash, and bentonite as a low permeable barrier, at the same time satisfying compressibility and strength criteria. Based on the study, it is noted that fly ash: bentonite of 50:50 mix satisfied the above mentioned performance evaluation criteria. However, further investigations are required to maximise the use of fly ash by improving its strength. Also, the recommended mix needs to be tested for its contaminant retention characteristics.

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