# Utilization of Fly Ash-Bentonite Mixture as an Alternate Liner Material

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## Introduction

A landfill liner should be a low permeable barrier which prevents a pollutant in a waste containment system from entering surface water, ground water and thus polluting them. The performance of the lining system is greatly affected by its hydraulic conductivity (Daniel 1987, 1990). Highly expansive clays such as bentonites (because of their low hydraulic conductivity, $k \leq 10^{-9}$ m/sec) mixed with certain geo-materials are used for the construction of hydraulic barriers. Bentonites consist of montmorillonite minerals; they are highly plastic in nature. Though bentonites are low permeable, they exhibit very low strength and very high volume change with variations in water content which is not acceptable in the case of hydraulic barriers. Compacted sand-bentonite mixtures are widely used as a liner material in municipal and hazardous waste containment (Akgun et al, 2015; Al-Rawas et al, 2006). In spite of its low hydraulic conductivity, the usage of sand-bentonite mixtures as liner material is decreasing now-a-days due to the non-availability of sand and growing environmental concerns related to its dredging. Therefore, there is an urgent need to find some alternate material for the construction of liners. This forms the scope to explore the usage of waste material like fly ash as an alternate liner material to sand. In this present work, the geotechnical investigation has been carried out to study the hydraulic conductivity, unconfined compressive strength, plasticity, and swelling characteristics of fly ash bentonite mixtures with bentonite content 5, 10 and 15 percent by dry weight respectively and suggested suitable fly ash bentonite mix considering the above criteria.

## Materials and Methodology

The materials used in this present study are fly ash and bentonite. The fly ash used in this present study was taken from Aditya Alumina Ltd. situated in Lapanga town in Sambalpur district, Odisha. The bentonite used in this study is sodium based bentonite which is commercially available in local market.

*Experimental procedure:* In this study, both physical and geotechnical properties of materials used were determined. Fly ash and bentonite mixtures with dry weight percentages of bentonite of 5, 10 and 15% were prepared i.e., FA+B (95:5; 90:10; 85:15). The liquid limit and plastic limit of above mentioned trial mixes were determined. Swelling characteristics for these trial mixes were obtained by conducting differential free swell index test. Optimum moisture content and maximum dry density were determined for these samples at four compaction energies of 355, 592, 1296 and 2700 kJ/m$^3$ respectively. Then, the hydraulic conductivity of these sample mixes compacted at their OMC and MDD are determined by falling head method. The effect of bentonite content and compaction effort on the strength of fly ash-bentonite mixes were determined by conducting unconfined compressive strength test.

## Results and Concluding Remarks

The effect of bentonite content on various characteristics of the fly ash- bentonite mixtures such as plasticity, swelling, compaction, hydraulic conductivity and strength were evaluated and are presented here. All the fly ash- bentonite trail mixes are satisfying the plasticity criteria and it was observed that the addition of bentonite to fly ash increases plasticity index of the mixture. This may be due to the fact that bentonite being a very high plastic soil when mixed with non-plastic fly ash, it imparts plasticity to fly ash-bentonite mixture. The increase of plasticity in fly ash-bentonite mixes is considered good in reducing the hydraulic conductivity ($\leq 1 \times 10^{-9}$m/sec). In 1994, Benson et al. conducted regression analysis for laboratory test results of 67 landfill sites data and suggested that, hydraulic conductivity ≤ 1 × $10^{-9}$ m/sec can be achieved if the liquid limit ≥ 20%, the plasticity index ≥ 7%. Differential free swell test results showed that addition of fly ash to bentonite has decreased the swelling behaviour of bentonite. After 95% fly ash addition to the bentonite, its free swell index got reduced to 6.7%. The decrease in swelling is due to the replacement of plastic fines of bentonite by non-plastic fines of fly ash (Phanikumar et al, 2007). The addition of fly ash to bentonite causes flocculation and cementation to take place and thus reducing the swelling characteristics of fly ash-bentonite mixes. Four different compaction energies such as standard Proctor (SP, 592 kJ/$m^3$), reduced standard Proctor (RSP, 355 kJ/$m^3$), modified Proctor (MP, 2700 kJ/$m^3$) and reduced modified Proctor (RMP, 1296 kJ/$m^3$) tests were carried out for three fly ash- bentonite mixtures (95:5; 90:10; 85:15). The results were analysed to determine the effect of bentonite content and compaction energy on hydraulic conductivity and unconfined compressive strength of above mentioned fly ash-bentonite mixtures and the same are presented in Figures 1 and 2 respectively.

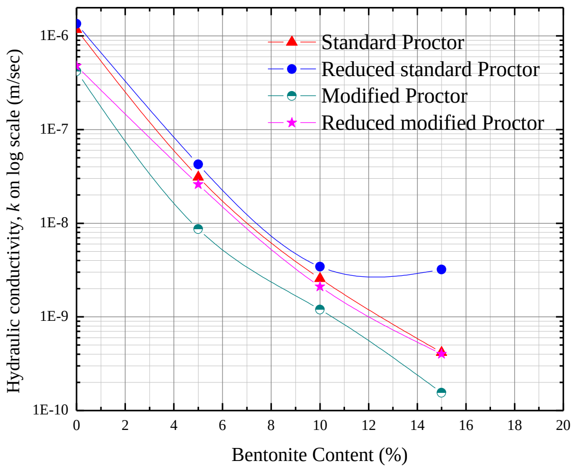


*Figure 1. Variation of hydraulic conductivity (k) with bentonite content*

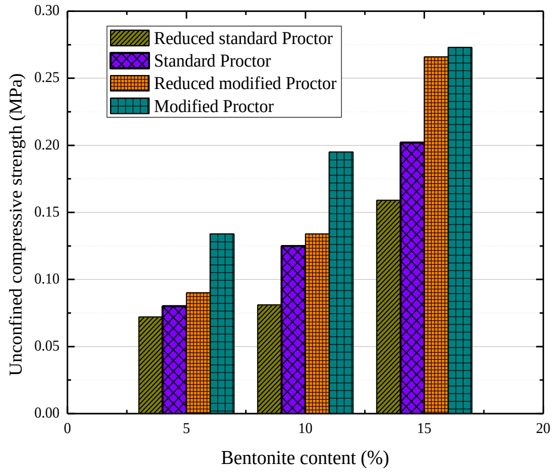


*Figure 2. Variation of UCS with bentonite content*

By comparing the experimental results with acceptable criteria for hydraulic conductivity ($k \le 10^{-9}$ m/sec), unconfined compressive strength ($\sigma > 0.2$ MPa), plasticity characteristics ($LL \ge 20\%$ and $PI \ge 7\%$), and swelling characteristics, the following fly ash-bentonite mixtures are suggested as liner material in waste containment system. They are:

- FA+B (85+15) mixture compacted under modified Proctor compaction
- FA+B (85+15) mixture compacted under reduced modified Proctor compaction
- FA+B (85+15) mixture compacted under standard Proctor compaction.

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