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GEO ENGINEERING PROPERTIES OF SEDIMENT FLYASH DEPOSIT STABILIZATION BY LIME PILE

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ABSTRACT:

Black cotton soil is considered to be problematic soil as it show major volume changes due to change in its moisture content. This volume change cause wide spread damages to building and roads necessitating stabilization of such soil prior to the construction. The present paper investigates the effectiveness of different stabilizing agent viz. lime, cement and fly ash with soil for improving its engineering properties. Soil samples were collected from district Morena, in state of Madhya Pradesh, in order to look in to the relative effectiveness, and arrive at appropriate proportion of stabilizing. (1) Lime, (2) Cement, (3) Fly ash alone and combination of (1) Lime– Cement, (2) Cement–Fly ash, (3) Fly ash-Lime are used to stabilize the soil. Quantity of stabilizing agent varied from 2% to 10% of the soil weight and the performance is evaluated by observing variation in various engineering properties like Liquid Limit, Plastic Limit, and Plasticity Index.

Keywords: *Fly ash, Lime, Cement, Liquid Limit, Plastic Limit, Plasticity Index and soil stabilization*.

INTRODUCTION

Coal ash, is a waste residue from thermal plant produced large amount thought the world every year. Coal ash is a general name given to both bottom ash and flyash. Current production of coal ash is estimated typically around 600 MT/year worldwide, with fly ash constituting about 75-80% of the total ash produced. Thus, the amount of fly ash generated from thermal power plants has been increasing throughout the world, and the Safe disposal of such large quantities of flyash from thermal power plants is a major concern. The percentage utilization of flyash is limited in India compared to most of the advanced countries and it is a mere of 5%. In India, most of the power plants adopt wet disposal system for disposing coal ash. In wet disposal system, large quantity of flyash along with bottom ash is mixed with 70–80% of water, transported in the form of slurry and deposited of in the ash pond, resulting in very soft deposits. Typically around 50,000 acres of such ash ponds has been located in various parts of India. The height of ash pond is raised every year due to scarcity of land in and around thermal power plant in order to increase the storage capacity of an ash pond. To increase storage capacity of ash pond various raising methods are in use which includes upstream, downstream and central raising methods. However, in many places the total height of the deposit exceeds 30 m and further increase in height may result in stability problem. Generally, the ash deposit placed in slurry form has a very low density and leads to problems such as liquefaction during earthquake, poor bearing capacity, large settlement, etc.

Number of research has been conducted in field as well as in laboratory to improve the density of ash by different techniques such as vacuum dewatering, electro osmosis, vibro compaction, stone columns, blasting

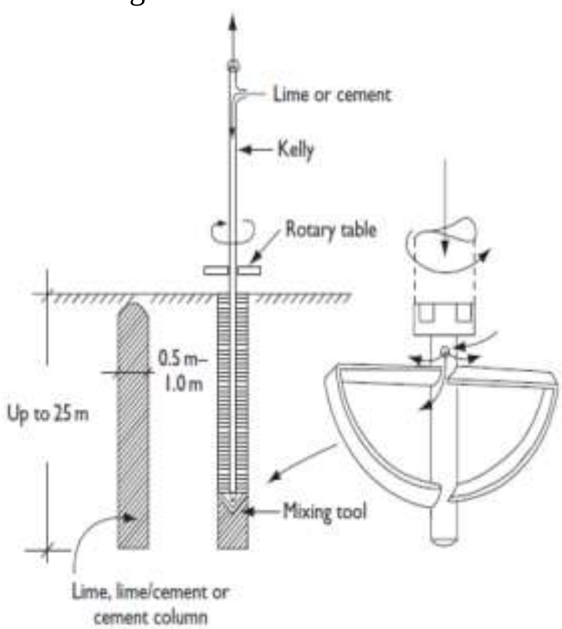
(Gandhi et al. 1997). Chand and Subbarao 2007 reported the effectiveness of in-place treatment of an ash deposit by hydrated lime column. Hydrated lime column was applied to laboratory model of deposited flyash slurry. It was reported that the lime column method found to increase the unconfined compressive strength and reduce hydraulic conductivity of pond ash deposits in addition to modifying other geotechnical parameters. Also showed the contamination potential of the ash leachates from deposited ash slurry is greatly reduced by lime column method that helps in mitigating the adverse environmental effects of ash deposits. Raju 2011 applied ground improvement using vibro techniques in stabilizing the flyash deposits. Initial field trials were carried out to assess the bearing capacity and also the lateral capacity of bored cast-in-situ pile foundations as a result of stone column installation. They showed that the successful application of vibro techniques to enhance the bearing capacity and lateral capacity of deep pile of the fly ash deposits and also mitigation of liquefaction potential of the site. More recently Kokusho et al. 2012 applied heavy compaction method (HCM) normally used for sandy soils for compacting flyash deposit. The improvement in flyash deposit was found from cone penetration tests were carried before and after the compaction which indicating obvious effects on soil properties and strength increase.

REVIEW OF LITERATURE

This paper describes the detailed review of literature performed towards highlighting the need of stabilization of flyash deposit using lime column technique.

Due to rapid growth in industrialization and economy, the large number of coal based thermal power plant has set up in various parts of country to meet the electricity demand. At the same time these power plants producing large amount of coal ash and its safe disposal of such ash is major concern. Usually flyash along with bottom ash mixed to form slurry and is disposed of in the storage ponds. In the process of sluicing and sedimentation of ash in the storage ponds considerable segregation of particles occurred resulting in formation of complex, heterogeneous,
sedimentary profiles. The engineering behavior of flyash slurry after sedimentation and consolidation processes under its own self-weight found to vary considerably than the compacted after dewatering. A metastable fabric formed in the sedimentation process which shows collapse potential of the materials ranged between 0.5 and 1% and also the flyash slurry exhibits a pseudo over consolidation effect, moderate collapsible behavior, and high compressibility at applied stresses Madhyannapu et al. (2008). The compressibility of sedimented fly ash is considerably greater than that of compacted fly ash specimens. The compression indices values of fly ash beds are dependent on the source material, sedimentation, and compaction procedures followed and the stress range over which it was subjected to consolidation test.
Densification of ash by any suitable techniques improves the engineering properties. The unit weight of the material mainly depends on the amount and method of energy application, grain size distribution, plasticity characteristics and moisture content at compaction Pandian, 2004. Flyash normally have air void content ranging between 5 to 15% at maximum dry density. Toth et al. (1988) reported that the higher void content tend to limit the buildup of pore

pressures during compaction allowing the fly ash to be compacted over a larger range of water content. One of interesting result provided by Gatti and Tripiciano (1981) that the compaction tests on coal ashes were collected from Vado Ligure Power Plant, Italy indicating maximum dry density varied between 11.4kN/m3 and 45kN/m3 and corresponding optimum moisture contents ranging between 28% and 36%. Also standard Proctor compaction curves provided by DiGioia et al. (1986) for Western Pennsylvania Class F fly ash shows that the maximum dry density ranged from 11.9 to 18.7 kN/m3 and optimum water content ranged from 13 to 32%.



Schematic diagram of installation of lime columns

MATERIALS AND METHODS

The aim of the investigation is to improve geotechnical characteristics of regimented and compacted flyash deposit as well as the potential of lime column method to achieve this and to study the strength distribution surround lime column. This paper describes the methodology and materials used to achieve the objectives. The flyash collected from local power plant and commercially available quick lime are two major materials used in the present investigation. Procedure for Sample preparation, sampling and testing techniques used for characterization of materials as well as development of experimental setup for investigation are reported in the following session.

Materials

The details of materials used in this study are given as follows.

Background

Lime can be used to improve or modify some of the engineering properties of fine grained soils. Thereby the strength and durability in the stabilized matrix can be improved. The amount of lime additive will depend upon number of parameters such as fines, liquid limit, plastic limit etc. The lime required for treatment of fine grained soils is more than the coarse grained soils.

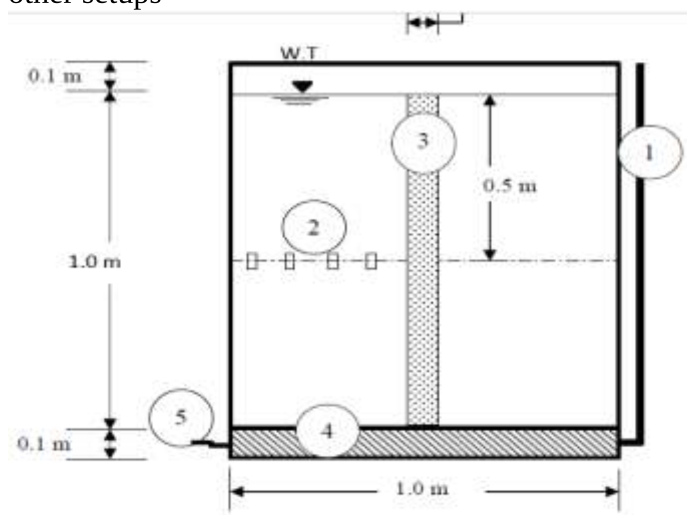
The improvement of the geotechnical properties of the soil mainly achieved by two basic chemical reactions (1) Short-term reactions including cation exchange and flocculation, where lime is a strong alkaline base which reacts chemically with clays causing a base exchange. Calcium ions (divalent) displace sodium, potassium, and hydrogen (monovalent) cations and change the electrical charge density around the lay particles. This results in an increase in the inter particle attraction causing flocculation and aggregation with a subsequent decrease in the plasticity of the soils.

(2) Long-term reaction including pozzolanic reaction, where calcium from the lime reacts with the soluble alumina and silica from the clay in the presence of water to produce stable calcium silicate hydrates (CSH), and calcium aluminate hydrates (CAH), and calcium alumino silicate hydrates (CASH) which generate long-term strength gain and improve the geotechnical properties of the soil. The use of lime for soil stabilization is either in the form of quicklime (CaO) or

hydrated lime Ca(OH)2. The chemical reaction between quicklime (CaO) and water 20 resulting in formation of hydrated lime Ca(OH)2 . The addition of water to quicklime
(CaO) is referred to as slaking.
High calcium quicklime + water = Hydrated lime + Heat
CaO + H2O = Ca(OH)2 + Heat
Various forms of lime sometimes used in lime stabilization applications are dehydrated dolomitic lime, monohydrated dolomitic lime, and dolomitic quicklime. In the present study, quicklime (CaO) in a dry form was used to form lime column. In general, the properties of lime treated sols are dependent on many factors such as soil type, lime type, lime percentage, and curing conditions (time, temperature, and moisture) and hence the strength and durability.

The prepared flyash slurries were allowed to fall from a constant height of 1 m into the test tank. Figure below shows the photograph of flyash slurry preparation in test tank with arrangements to measure variation of temperature. The test setup for sedimentation consisted of a circular tank open at the top and fitted with a drainage bed and a perforated base plate at the bottom. Before placing slurry in the test tank, a steel casing of size equal to size of lime column covered with
fiber mesh of small aperture was placed exactly at the center of test tank and a number of temperature sensors were also inserted at different predetermined places of tank to record the variation of temperature in the installation and hydration of lime column.

Photograph of slurry flyash in test tank and other setups



Schematic diagram of lime column installed along full length of deposit in a test tank with other setups.

RESULTS AND DISCUSSION

Huge quantities of coal fly ash are produced every year as a residue from coal based thermal power plants in all over the world. Safe disposal and utilization of such large quantities of flyash is a major concern. The percentage utilization of flyash is rather limited in India than most of the advanced countries. Coal ash is a general term given to both flyash and bottom ash. Normally both fly ash and bottom ash from thermal power plant is sluiced with sufficient amount of water to form flyash slurry, transported and deposited in pond in the vicinity of plants. The clear decanted water after settling of flyash particle is discharged into a natural stream. Such ash ponds normally forms a soft ground of high water content and high fines content with small strength and high deformability particularly under the water table. Typically 20,000 ha of land are occupied by ash ponds. Various problems being encountered with the ash ponds includes dusting problems, increasing the level of solid suspended particulate materials in the air, low bearing capacity and large settlement. Hence it is considered to be unsuitable for supporting any structural load. Also, the leachates emanating from the ash ponds may lead to contamination of surface water and ground water bodies, as well as soils depending on the amount of toxic elements it contains.

A more economical and suitable soil improvement method such as the lime column method may possibly be used to convert suitable for construction purposes. Present work used lime column method to improve geotechnical characteristics of sedimented flyash deposits. The variation of strength (both vertical and horizontal direction) surround lime column in compacted and slurry fly ash materials are studied in the large scale laboratory model.

Table: Physical Properties of Flyash

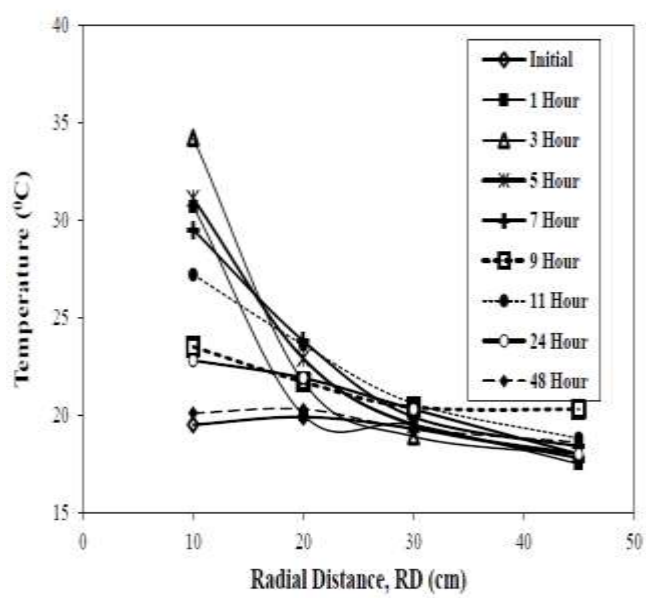
Physical parameters	Values
Colour	Medium grey
Silt size	8.13%
Shape	Rounded/sub-rounded
Uniformity coefficient, Cu	8.34
Coefficient of curvature, Cc	2.08
Specific Gravity, G	2.44
Plasticity Index	Non- plastic

Permeability of flyash with depth (lime column installed at full depth)

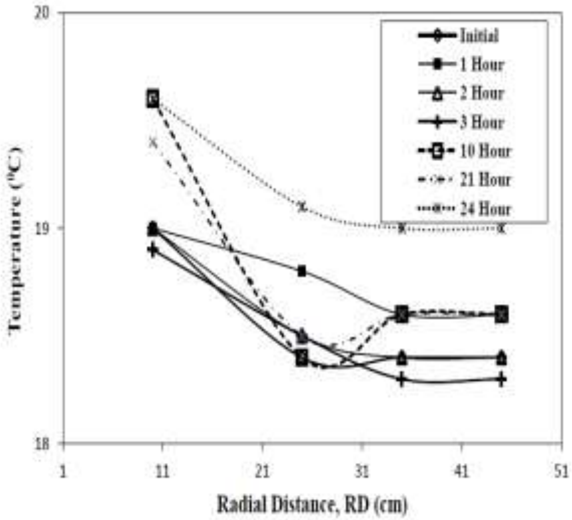
Temperature

The variation of temperature after inclusion of lime column (both 0.2m and 1m) in sediment flyash slurry was shown below.

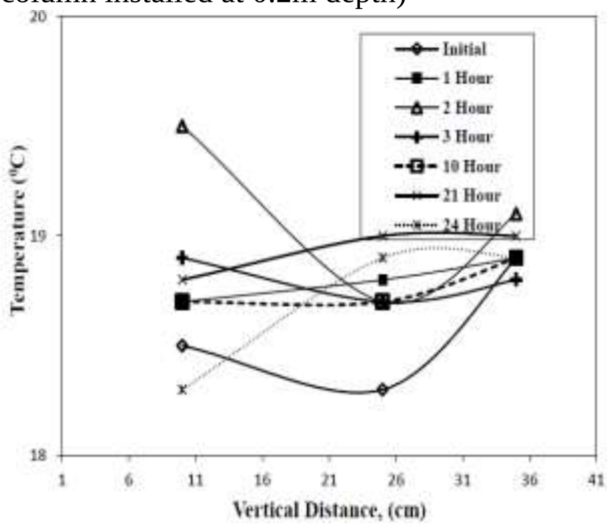
Depth (cm)	Hydraulic Conductivity in (cm/sec) Radial Direction in cm			
	10	20	30	45
10	$1.196X10^{-5}$	$1.5X10^{-5}$	$2.44X10^{-5}$	$2.0X10^{-5}$
30	$1.85X10^{-5}$	$2.43X10^{-5}$	$2.92X10^{-5}$	$1.77X10^{-5}$
50	$1.38X10^{-5}$	$1.49X10^{-5}$	$2.44X10^{-5}$	$3.722X10^{-5}$
70	$1.09x10^{-5}$	$1.31X10^{-5}$	$1.74X10^{-5}$	$1.87X10^{-5}$
90	$1.75X10^{-5}$	$1.75X10^{-5}$	$1.46X10^{-5}$	$2.21x10^{-5}$



Variation of temperature with RD (lime column installed at full depth)



Variation of temperature with RD (lime column installed at 0.2m depth)



Variation of temperature with vertical distance (lime column installed at 0.2m depth)

In all the test cases samples were kept saturated. There are three possible mechanisms which causes increase or decrease of strength. The development of suction in the pore fluid may reduce due to saturation of the specimens that fill the voids to certain extent. Saturation may soften the specimens and thus leads to reducing the shear strength. During saturation the specimens may get sufficient moisture for pozzolanic reaction and hence the shear strength may increase on formation of reaction products. In this investigation, it is observed that the strength of sedimented fly ash in the top portion has reduced compared to bottom and middle portion for 45 days and 90 days cured samples which implies that the former two mechanisms i.e., probability of low suction development in soaked specimens and softening of the specimens have dominated over the third mechanism of gain in shear strength due to pozzolanic reaction in presence of sufficient moisture. Test results of saturated specimens may be used in practice to avoid the assessment of development of suction in partially saturated specimens. The reduction in strength due to soaking is also governed by the hydraulic conductivity of the stabilized matrix. (See variation of moisture content).

The reduction in strength at bottom of sediment fly ash occurs possibly due to low solubility of lime. In lime pile technique, the soil is stabilized through the physico-chemical reactions assisted by ion migration. Usually in lime piles, greater portion of the lime stays at the bottom of the borehole without getting dispersed into the surrounding soil due to the low solubility of lime, and takes longer time for migrating into the surrounding soil.

Summary and Conclusions

In this investigation, potential of lime column for stabilization of ash pond was evaluated for converting it to a usable land can be utilized for a broad range of purposes, such as suburban housing, light commercial building, and utilities etc. Two different states of flyash (slurry and compacted) were considered as expected in the field. The improvements in strength of the flyash mass surround lime column are studied through different conventional test methods such as unconfined compressive strength and direct shear test. An

experimental investigation to assess the potential of in-place treatment of an ash deposit was carried out. In the present work, emphasis has been given on application of the in-place lime column method for stabilization of
sedimented pond ash deposits. Since various disadvantages such as excavation, mixing, and transportation of huge quantity of ash from the ash ponds or disposal sites in the case of conventional mixing method can be avoided and at the same time improvement in the engineering properties of the whole deposit can be achieved thereby these abandoned sites may be used for construction purposes.

The lime column method was found to be effective in increasing the UCS and reducing hydraulic conductivity of pond ash deposits along with modifying other geotechnical parameters including water content, density. An increase of 263.26% of UCS at a radial distance of 10 cm at top portion compared to the unstabilized ash was observed. This may due to in-place lime stabilization confirms the pozzolanic nature of the ash, and thus its capability to react with lime and develop substantial strength.

The formation of cementitious compounds reduces the void spaces and in the interconnectivity of pore channels, thereby reducing hydraulic conductivity. Also this method is also found to be useful in reducing the contamination potential of the ash leachates.

It was observed that the lime column inclusion enhance the strength of sedimented flyash deposit with stabilization time. Also significant improvement in strength was observed up to a horizontal distance of 3 D (where D is the diameter of lime column) from the center of column and vertical distance of 4 D from bottom of lime column. A comparative study showed that the strength of stabilized mass is much higher than the un-stabilized one. The method has also proved to be useful in reducing the contamination potential of the ash leachates, thus mitigating the adverse environmental effects of ash deposits.

REFERENCES

Bell, F. G. (1988), "Stabilisation and Treatment of Clay Soils with Lime," Part 1 – Basic principles. Ground Engineering, 21, 10 - 15.

Bin-Shafique, S., Benson, C., Edil, T. and Hwang, K., (2006), "Leachate Concentrations from Water Leach and Column Leach Tests on Fly – Ash Stabilized Soil," *Environ. Eng. Science*, 23(1), 51-65.

Broms, B.B. and P. Boman. (1975). "Lime Stabilized Column." Proceedings 5th Asian Regional Conference on Soil Mechanic and Foundation Engineering, Vol. 1, pp. 227-234.

Chand, S K. and Subbarao, C. (2007), "In-Place Stabilization of Pond Ash Deposits by Hydrated Lime Columns" *J. Geotech. and Geoenvironmental Eng*., 133(12), 1609–1616.

DiGioia, A M., Mclaren, R J., Burns, D L., and Miller, D E. (1986), "Fly Ash Design Manual For Road And Site Application," vol. 1: Dry or conditioned placement, Manual prepared for EPRI, CS-4419, Research project 2422-2, Interim report, Electric Power Research Institute, Palo Alto, California, Gandhi, S R., Dey, A K., and Selvam, S. (1999), "Densification of Pond Ash By Blasting", *J. Geotech and Geoenviron Eng.*, 125, 0889–0899.Gatti, G., and Tripiciano, L. (1981), "Mechanical Behaviour of Coal Fly Ashes," *In:Proc. of 10th Int. conf. on Soil mech. and found. Eng.,* Stockholm, 2, 317-322.

Ghosh, A., & Subbarao, C. (1998), "Hydraulic Conductivity and Leachate Characteristics of Stabilized Fly Ash," Journal of Environmental Engineering, 124(9), 812-820.

Ghosh, A., & Subbarao, C. (1998), "Hydraulic Conductivity and Leachate Characteristics of Stabilized Fly Ash," Journal of Environmental Engineering, 124(9), 812-820.

Ghosh, A., & Subbarao, C. (2007), "Strength Characteristics of Class F Fly Ash Modified with Lime and Gypsum," Journal of geotechnical and geoenvironmental engineering, 133(7), 757-766.

Ghosh, A., and Subbarao, C. (2006), "Tensile Strength Bearing Ratio and Slake Durability of Class F Fly Ash Stabilized with Lime and Gypsum," *J. of Mater in CivilEng*., 18, 18-27.

Gray, D H., and Lin, Y K. (1972), "Engineering Properties of Compacted Fly Ash," *J. of Soil Mech. Foundation Eng.,* 98, 361-380.