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GEO-ENGINEERING PROPERTIES OF SEDIMENTED FLYASH DEPOSIT STABILIZED BY LIMEPILE

Jabba Hima Teja Sree[1], M.Ramakrishna M.E[2], K.Ramasesharao[3]
[1]Postgraduate Student, [2]Professor, Head of Dept of Civil Engg, [3]M.Tech Asst. PROFFESSOR
Srisunflower College of Engg & Tech, Lankapalli, Krishana (A.P)

Abstract:** Coal based thermal power plant has created over 50,000 acres of ash ponds in India, with approximately 2500 acres of additional ponds created for a 500-MW power plant and is filled with ash up to 10 m in height within a period of 5 years. Presently, 190 MT of fly ash is generated every year and it is likely to increase up to 350 MT by 2018-19. 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 in situ water content of deposits typically varied from 10% to 110% and ultimate bearing capacity of not more than 95kN/m2. Various ground improvement Techniques have been applied to improve the geotechnical characteristics of these lands and or to enhance storage capacity and or to make it suitable for construction purposes. Since construction of buildings or utilities on these lands by conventional methods is not possible because of low strength flyash forms a very soft ground and highly compressible due to high water content. Also ponding of the ash generally found to reduce its self-hardening or pozzolanic properties. In the present work, investigations were made to study the strength distribution of sedimented flyash deposit surrounded by lime column over a stabilization period of 90 days. Flyash slurry was prepared and allowed to fall from a constant height of 1 m in a test tank having 1m diameter and 1.2 m height. Prior to saturation, a single lime column of 0.1 m diameter over full length of deposited slurry was installed in the test tank after the initial sedimentation period of 30 days. It is reasonable to assume that the lime will flow easily downward into flyash deposit in vertical direction and the strength may also increase with the availability of lime. To obtain variation of strength in vertical direction, lime column of 0.2 m height was made in other tank in a similar manner. A series of uniaxial strength and direct shear tests were performed on the samples extracted at various depths and radial distances. 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

***Keywords:** lime column, sedimented flyash, standard proctor density, pozzolanic reaction, unconfined compressive strength, shear strength parameters.*

I. 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. A laboratory program was undertaken to systematically investigate the potential of the Lime Column Method (LCM) normally used for stabilizing soft soils for improving sedimented flyash deposit. A series of uniaxial strength and direct shear tests were performed on the samples collected at various depths and radial distances. 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.

II. LITERATURE SURVEY

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.

Horiuchi et al. 2000 used coal ash slurry as a back fill material on the wall of cofferdam, there was significant improvement in strength development with time was observed. Also they presented the effective use of flyash slurry in variety of applications listed below

- Underwater fills
- Light weight backfills
- Light weight structural fills etc.

Development of strength of flyash slurry with time is affected by parameters such as temperature and additives and considered to be major concern for making appropriate slurries. Also high calcium content of flyash helps to gain in strength of slurry with time due to pozzolanic reaction. From the one-dimensional consolidation of sedimented stowed pond of the mines, Mishra and Das (2012) studied experimentally the variation of coefficient of consolidation of the sedimented stowed pond ash and were found to be in range of 0.0195–0.1882 cm2/min. The value of consolidation coefficient decreases with increment in applied load and time indicating that the stowed pond ash mass will undergo gradual settling and not suffer large deformation.

Indraratna et al. (1991) reported that the high value of compressive strength in case of unsoaked specimen possibility due to suction development in the pore fluid. There are three possible mechanisms which responsible for gain/ loss of strength of flyash while soaking. 1) Soaking of the specimens may fill the specimen voids to certain extent and thereby it reduces development of suction in the pore fluid. 2) Soaking may cause softening of the specimens and thus reducing the shear strength. 3) During soaking, the specimens may get sufficient moisture required for pozzolanic reaction which may help to increase the shear strength by the formation of reaction products. Also the density found to be an important parameter responsible for the strength, compressibility and permeability of fly ash.

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%.

III. MATERIALS AND METHODS

The aim of the investigation is to improve geotechnical characteristics of sedimented 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 chapter 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 USED

Fly ash : Flyash particles are spherical in shape whose size ranges from 0.5 µm to 100 µm. According to ASTM C618, 75% to 80% is constituted by low lime flyash in the total production of coal ash which generally comes under class F flyash. However, heavier and coarser coal ash collected from the bottom of furnace is generally referred as bottom ash which constitutes around 20–25% of the total ash production. Although these three kinds of coal ashes possess different engineering properties, they are synonymously called ‘fly ash’ unless otherwise specifically referred. Coal ashes mainly consist of silicon dioxide (SiO2), aluminum oxide (Al2O3) and iron oxide (Fe2O3). However, silicon dioxide (SiO2) may present in two forms: 1) amorphous, which is rounded and smooth. 2) Crystalline, which is sharp, pointed and hazardous. Fly ashes are generally highly heterogeneous, consisting of a mixture of glassy particles with various identifiable crystalline phases such as quartz, mullite, and various iron oxides.

Class F fly ash:

Class F fly ash produces in the burning process of harder, older anthracite and bituminous coal. Class F fly ash is pozzolanic in nature, and contains less than 10% lime (CaO).

Class C fly ash:

This is produced from the burning of younger lignite or sub bituminous coal, in addition to having pozzolanic properties, also has some self-cementing properties. In the presence of water, Class C fly ash will harden and gain strength over time. Class C fly ash generally contains more than 20% lime (CaO). Unlike Class F, self-cementing Class C fly ash does not require an activator. Alkali and sulfate (SO4) contents are generally higher in Class C fly ashes.

Lime

The commercially available superior grade quick lime was used to prepare lime column. Quicklime is manufactured by chemically transforming calcium carbonate (limestone – CaCO3) into calcium oxide (CaO). 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 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

IV. METHODOLOGY

Specific Gravity

The specific gravity of fly ash were determined using pycnometer method as per IS: 2720-Part 3 (1980).

Particle Size Distribution

Particle size distribution of flyash was determined using hydrometer method in accordance with IS: 2720- part 4 (1975).

Compaction Test

The water – density relation of flyash using light compaction was determined in accordance with IS: 2720-Part 7 (1983).The same was performed to determine the relationship between dry density and moisture content of the flyash as per the procedure given in IS: 2720-Part 8 (1983).

Unconfined Compressive Strength Test

The UCS tests were conducted according to IS: 2720-Part 10 (1991).The test was continued till failure or maximal vertical strain according to IS: 2720-Part 10 (1991).

Direct Shear Test

The shear parameters of flyash specimens were determined as per IS: 2720 (Part 13) 1986.

Permeability Test

The coefficient of permeability of flyash specimens (both stabilized and unstabilized) were determined as per IS: 2720 (Part 36) 1975.

V. RESULTS

Physical Propeties 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

Geotechnical properties of Flyash

Property	Flyash
1.Compaction characteristics From Light compaction or Standard Proctor test a)Maximum dry density (kN/m3) b)Optimum moisture content(%) From Heavy compaction or Modified Proctor test a)Maximum dry density(kN/m3) b)Optimum moisture content(%)	11.41 41.00 12.25 34.20
2.Permeability (cm/sec) of a)sample compacted at standard proctor density b)sample poured in slurry form	 1.86x10-5 2.84x10-5
3.Shear strength parameters from direct shear test of sample compacted at standard proctor density a)cohesion,cp(kPa) b)friction angle,Øn	 25.22 42.6
3.Shear strength parameters from direct shrear test in slurry state a)cohesion, cp(kPa) b)friction angle, Øp	 16.94 37.00

Geotechnical Properties of Sedimented Flyash slurry Surround Lime Column

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

depth (cm)	Hydraulic Conductivity in (cm/sec)			
	Radial Direction in cm			
	10	20	30	45
10	1.84x10^{-5}	1.93x10^{-5}	1.1x10^{-5}	2.4x10^{-5}
30	1.83x10^{-5}	1.56x10^{-5}	1.38x10^{-5}	1.16x10^{-5}
50	1.84x10^{-5}	1.51x10^{-5}	1.33x10^{-5}	1.21x10^{-5}
70	1.75x10^{-5}	1.56x10^{-5}	1.43x10^{-5}	1.84x10^{-5}
90	1.28x10^{-5}	1.46x10^{-5}	1.69x10^{-5}	2.15x10^{-5}

Permeability of flyash with depth(lime column installed at 0.2m depth)

depth (cm)	Hydraulic Conductivity in (cm/sec)			
	Radial Direction in cm			
	10	20	30	45
10	2.47x10^{-5}	2.8x10^{-5}	3.10x10^{-5}	2.11x10^{-5}
30	1.55x10^{-5}	1.57x10^{-5}	1.50x10^{-5}	1.72x10^{-5}
50	1.62x10^{-5}	1.65x10^{-5}	1.50x10^{-5}	1.55x10^{-5}
70	1.24x10^{-5}	1.4x10^{-5}	1.46x10^{-5}	1.86x10^{-5}
90	9.85x10^{-5}	1.15x10^{-5}	1.87x10^{-5}	1.10x10^{-5}

Geotechnical Properties of Compacted Flyash Surround Lime Column

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

depth (cm)	Hydraulic Conductivity in (cm/sec)			
	Radial Direction in cm			
	10	20	30	45
10	1.95x10^{-5}	1.50x10^{-5}	2.44x10^{-5}	2.01x10^{-5}
30	1.85x10^{-5}	2.43x10^{-5}	2.91x10^{-5}	1.78x10^{-5}
50	1.37x10^{-5}	1.50x10^{-5}	2.45x10^{-5}	3.72x10^{-5}
70	1.08x10^{-5}	1.31x10^{-5}	1.74x10^{-5}	1.84x10^{-5}
90	1.75x10^{-5}	1.75x10^{-5}	1.46x10^{-5}	2.21x10^{-5}

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

depth (cm)	Hydraulic Conductivity in (cm/sec)			
	Radial Direction in cm			
	10	20	30	45
10	$1.22x10^{-5}$	$1.61x10^{-5}$	$2.29x10^{-5}$	$1.33x10^{-5}$
30	$1.27x10^{-5}$	$2.63x10^{-5}$	$2.45x10^{-5}$	$2.1x10^{-5}$
50	$1.00x10^{-5}$	$2.0x10^{-5}$	$1.38x10^{-5}$	$1.26x10^{-5}$
70	$1.04x10^{-5}$	$2.34x10^{-5}$	$1.95x10^{-5}$	$1.13x10^{-5}$
90	$6.86x10^{-6}$	$7.71x10^{-6}$	$6.64x10^{-6}$	$8.28x10^{-6}$

VI. CONCLUSION

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.

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