An Experimental Study on Geo Engineering Properties of Sedimented fly ash deposit Stabilized by lime pile

Nandikola Jithendra Kumar[1], J. Bharath Kumar[2], M Mujahid Ahmed[3]

[1]M. Tech Scholar, Department of Civil Engineering, St John's college of Engineering and Technology Yerrakota, Yemmiganur, AP, India, 518360.

[2]Assistant Professor, Department of Civil Engineering, St John's college of Engineering and Technology Yerrakota, Yemmiganur, AP, India, 518360.

[3]Associate Professor, Department of Civil Engineering, St John's college of Engineering and Technology Yerrakota, Yemmiganur, AP, India, 518360.

Abstract *Over the course of five years, ash ponds of up to ten meters in height were filled up by a coal-based thermal power station in India, which had already covered more than 50,000 acres of land. To accommodate a 500 MW power plant, an additional 2,500 acres of ponds had to be constructed. Fly ash production is now at 190 MT per year and is projected to reach 350 MT in 2018–19. Complex, heterogeneous sedimentary profiles were formed as a consequence of substantial particle segregation that occurred during the sluicing and sedimentation of ash in the storage ponds. Deposits' in-situ water content ranged from 10% to 110%, and their ultimate bearing capability was no more than 95 kN/m2. Diverse ground-level enhancement These lands have had their geotechnical properties improved, their storage capacity increased, or their suitability for development made acceptable by using various techniques. Because of its high water content and poor strength, fly ash creates an extremely soft ground, making traditional techniques of building or constructing utilities on these sites impossible. It has also been observed that ash's self-hardening or pozzolanic characteristics are diminished when it pools. In this research, we looked at the strength distribution of a 90-day stabilization period of sedimented fly ash deposit encircled by a lime column. In a test tank with a diameter of 1 meter and a height of 1.2 meters, fly ash slurry was made and then allowed to fall from a constant height of 1 meter.*

After the first 30 days of sedimentation, a single lime column in the test tank with a diameter of 0.1 m and a length equal to the deposited slurry was placed there before saturation. The vertical flow of lime into the fly ash deposit is likely to be easy, and the strength may rise in proportion to the lime's availability. In a different tank, a lime column of 0.2 m in height was constructed in a same fashion to achieve strength variation in the vertical direction. The samples that were taken at different depths and radial distances were subjected to a battery of direct shear and uniaxial strength tests. As the sedimented fly ash deposit stabilizes, the strength of the deposit is increased by the addition of lime columns. At horizontal distances of 3 D (where D is the lime column diameter) from the column center and 4 D (the vertical distance from the bottom of the lime column), there was a notable increase in strength. The stabilitśy of stabilized mass is much greater than that of unstabilized mass, according to the comparison research. In addition to lowering the possibility for contamination of the ash leachates, the approach has been beneficial in reducing the negative environmental consequences of ash deposits.

1. 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 fly ash deposit. A series of uni axial 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.

A developing country like India which has a large geographical area and population, demands vast infrastructure i.e. network of roads and buildings. Everywhere land is being utilized for various structures from ordinary house to sky scrapers, bridges to airports and from rural roads to expressways. Almost all the civil engineering structures are located on various soil strata. Every Civil Engineering structure is to be found on the soil. The soil on which the structure is to be built should be capable of withstanding the load to be imposed on it. However, naturally there exist problematic soils to be used as foundation or construction materials, such as expansive soils, whose engineering characteristics are mainly affected by the fluctuation of moisture content. Soil stabilization is the process which involves in enhancing the physical properties of the soil in order to improve its strength, durability by mixing it with additives. Soil stabilisation can also be defined as the controlled modification of soil texture, structure and physical as well as mechanical properties.

The methods of stabilisation can be broadly classified as physical, mechanical or binding. Physical stabilisation is the modification of soil particle size distribution and plasticity by the addition/subtraction of different soil fractions in order to modify its physical properties. Mechanical stabilisation is the modification of porosity of soil and inter-particle friction/ interlock by compaction or other means. In line with this, the selection criteria for these stabilisation techniques should be the plasticity index and the relative amount of cohesive material as the key parameters. However, there are several other options in addition to lime and cement, for soil stabilisation including fibre reinforcement and polymers. Other stabilisers include chemical admixtures that offer specific functional properties such as set acceleration/retardation of hydraulic binders, plasticisers and hydrophobic admixtures.

2. LITERATURE STUDIES

Garzon et al. (2016) investigated the stabilization and improvement in engineering properties of a Spanish phyllite clay achieved by the addition of 3, 5 and 7 wt.% lime. Consistency limits, compaction, California Bearing Ratio, swelling potential and water-permeability are the geotechnical properties investigated. The addition of 3 wt.% lime was sufficient to get the desired results. Also, the lime percentage significantly reduced the plasticity index value, without any swelling under soakage.

Amidi and Okeiyi (2017) conducted a laboratory study to evaluate and compare the stabilization effectiveness of different percentages (0, 2.5, 5, 7.5, 10%) of quick and hydrated lime when applied separately to locally available lateritic soil. It was found that the quicklime reduced the plasticity while hydrated lime resulted in higher dry unit weight. Also, when soil sample was treated with quicklime, it resulted into higher UCS especially at higher dosages (7.5 and 10%). From the aforesaid results, quicklime is considered to have shown superior engineering properties and therefore creates a more effective stabilization alternative for the soil.

Soheil et al. (2017) investigated the effects of curing on geotechnical properties of stabilised kaolinitic clay with lime and geogrids. Geogrid was added to the lime-stabilised-clay in four layers at constant intervals and the engineering properties were also observed after the curing times. Based on the results the geotechnical properties of clay were improved significantly by adding lime and geogrid, however, by increasing the percentages of lime, the brittleness index increased and the deformability index decreased.

3. MATERIALS USED

3.1 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). Usually requires a cementing agent, such as Portland cement, quicklime, or hydrated lime, with the presence of water in order to react and produce cementitious compounds. It contains more percentage of glassy silica and alumina. Alternatively, the addition of a chemical activator such as sodium silicate (water glass) to a Class F ash can leads to the formation of a geopolymer.

3.2 Lime

The commercially available superior grade quick lime was used to prepare lime column. Quicklime is manufactured by chemically transforming calcium carbonate (limestone – $CaCO_3$) into calcium oxide (CaO).

3.3 METHODOLOGY USED

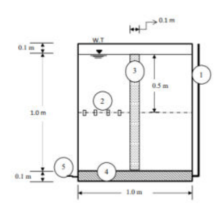
The present experimental program investigates the efficacy of lime column method to stabilize sedimented fly ash deposits. A large scale laboratory model test tank was made in which fly ash slurry allowed to fall from constant height. Both sedimentation and consolidation under its own weight of fly ash slurry were allowed to occur for a period of 30 days in a laboratory environment simulated as close to the same expected in ash ponds. Lime column was installed in center of sedimented fly ash deposit after initial sedimentation period and the sample was saturated. Unconfined compressive strength tests, direct shear tests and hydraulic conductivity tests were conducted on fly ash specimens extracted from the sedimented fly ash deposits at different radial and vertical distances. The improvement in the geotechnical parameters was observed over a stabilization period of 90 days. Similar studies were extended to compacted fly ash samples.

3.3.2 Preparation of Flyash Sample in Test Tank

In the present study, four numbers of test tanks of size 1.1 m diameter and 1.2 m height was used. The schematic diagrams of test tank with sample and other arrangements. Two types of flyash samples were prepared i.e. sedimented flyash slurry deposit and compacted flyash. Detailed procedures adopted for preparation of samples have been mentioned in the following sections.

3.3.3 Simulation of Sedimentation of Ash Slurry

The amounts of water required for the flowable flyash slurry were determined from step-by-step water addition, and mixing of flyash. Significant variation in viscosity was observed with mixing time of flyash slurries. A conventional mixer machine was used to prepare the slurries in the laboratory. Mixing time of 10 minutes was adopted to obtain good workable flyash slurry. The average initial moisture content was determined by random sampling method. Finally, to obtain good flowable flyash slurry water to flyash ratio was fixed at 75%.



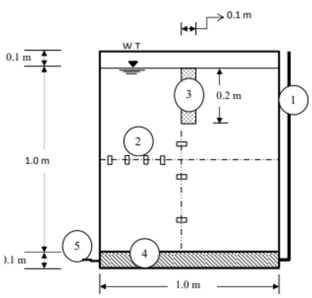
Schematic diagram of lime column installed along full length of deposit

Photograph of slurry fly ash in test tank and other setups

Above fig shows the casing and sensors holder. After filling the test tank with flyash slurry, consolidation due to the self-weight of fly ash slurry deposited hydraulically in an ash pond/lagoon has been simulated in the laboratory environment. After all the ash particles settled into the bottom test tank, the excess water was removed through the bottom drainage arrangement.

Compaction of Fly ash in Test Tank

Similar test tanks and setups as shown in Figs 3.1 were used to carryout lime column experiments in case of compacted fly ash. Fly ash was compacted at Standard Proctor MDD 11.4 kN/m3 and 92.7% of OMC (41.04 %) values.



Schematic diagram of test tank for 0.2 m lime column and other setups

1) Stand pipe
2) Temperature sensors
3) Lime column with casing
4) Sand bed (drainage layer)
5) Drainage pipe (outlet)

The values of dry density and water content of the flyash used in the study were guided by the values typically expected in field situations. For each test tank, the weight of flyash required to compact at proctor density is 8.59 kN. The volume of test tank was divided into ten equal parts by marking horizontal lines. The required bulk mass of flyash for each layer was then divided into 8 equal fractions. Each fraction of flyash was thoroughly mixed using conventional laboratory mixer machine with desired amount of water to get wet flyash mass with average moisture content of 38 %. At the end of thorough mixing, the fractions were compacted in the test mould using rammer.

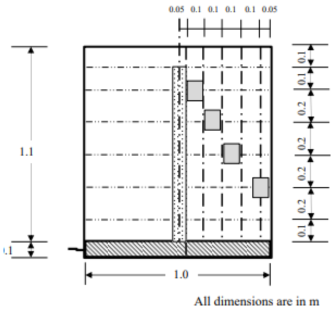
Installation of Lime Column

After the initial sedimentation period of 30 days, a small amount of water was standing in the casing and was removed using vacuum pump, and a quick lime powder was poured at the central casing in the test tank. The mass of lime required for lime column at full length of flyash bed was found to be 5.5 kg. The required bulk mass was divided into ten equal portion. After placing each portion of total mass, a slight compaction using specially fabricated hammer was adopted. Thus, a column of lime was neatly formed at the center of the sedimented flyash bed. (Note: This study aims at to study strength distribution of flyash mass due to lime column inclusion and hence a volume change due to expansion of lime column was prevented with the help of casing). However in practical cases the improvement was normally achieved by both expansions and migration of ions due to inclusion of lime column.

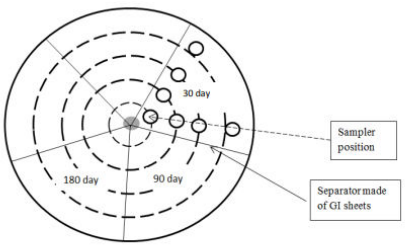
Sampling Program

Sampling tubes having 10 cm external diameter and 15 cm length were used to extract samples in order to determine the geotechnical parameters such as water content, density, shear strength parameters, unconfined compressive strength and hydraulic conductivity. Shear strength parameters were determined for samples collected from radial distance of 20 cm, 30cm and 45cm at various depths of 10cm, 30cm, 50cm, 70cm and 90cm respectively. In order to obtain samples after stabilization periods of 30 days and 90 days, a partition was made by inserting thin GI sheet into the flyash bed to avoid caving and or heaving at the time of sampling. The partition was done by inserting individual GI sheets. Hydraulic jack reaction frame assembly was used for inserting GI sheets into the flyash mass so that the disturbance of the surrounding mass will be avoided. The excess water standing over the flyash bed was removed by using vacuum pump.

The density and moisture content of fly ash for different predetermined locations and positions were determined from the samples directly obtained from the bed. Enough care was taken in the process of insertion of sampler into the ash bed to obtain least disturbed samples for the representative testing. Similar procedure was adopted for sampling corresponding to different stabilization periods.



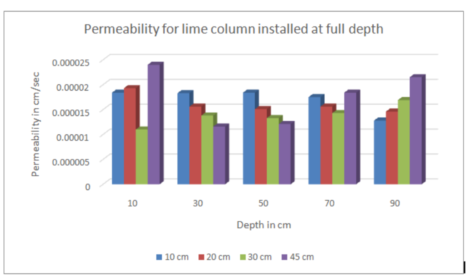
Elevation of test tank with detailed Sampling location



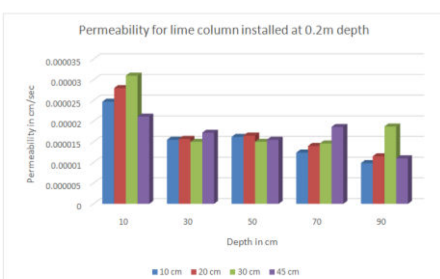
Plan view of test tank with detailed Sampling location

4. RESULTS AND ANALYSIS

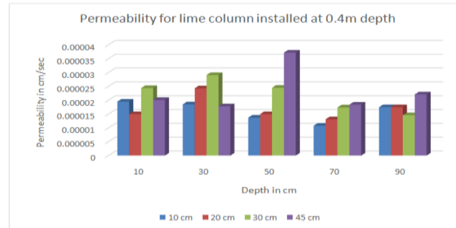
4.1 Permeability Results



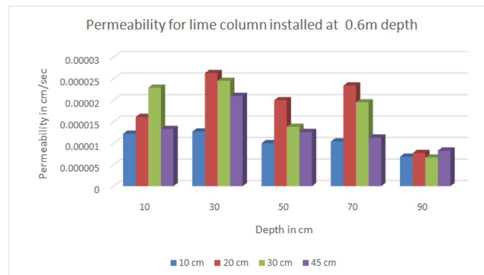
Permeability of fly ash with depth (lime column installed at full depth)



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

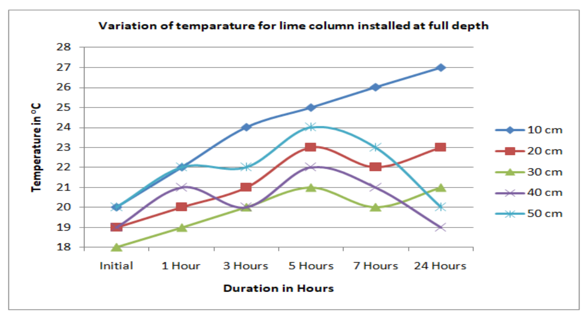


Permeability of fly ash with depth (lime column installed at 0.4m depth)

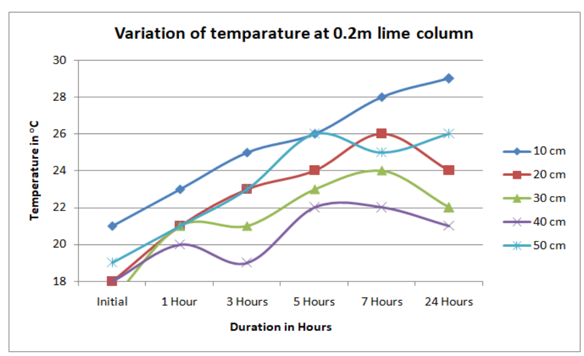


Permeability of fly ash with depth (lime column installed at 0.6m depth)

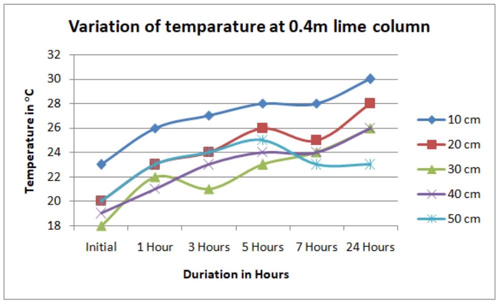
4.2 Temperature variation test results



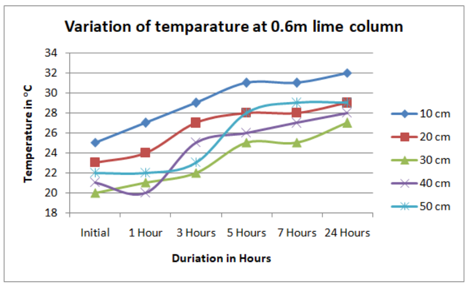
Temperature of fly ash with depth (lime column installed at full depth)



Temperature of fly ash with depth (lime column installed at 0.2m depth)



Temperature of fly ash with depth (lime column installed at 0.4m depth)



Temperature of fly ash with depth (lime column installed at 0.6m depth

5 CONCLUSIONS

From this investigation the following conclusions were made

1. The improvements in strength of the fly ash mass surround lime column are studied through different conventional test methods such as unconfined compressive strength and direct shear test.
2. 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.
3. 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 un stabilized ash was observed.
4. 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.
5. The formation of cementitious compounds reduces the void spaces and in the interconnectivity of pore channels, thereby reducing hydraulic conductivity.
6. It was observed that the lime column inclusion enhance the strength of sedimented fly ash deposit with stabilization time.
7. 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

[1] A. A. Amadi and A. Okeiyi (2017), “Use of quick and hydrated lime in stabilization of lateritic soil: comparative analysis of laboratory data”, “International journal for geo-engineering, Vol- 8 pg: 1 -13.

[2] AbiolaAyopoAbiodun and ZaliheNalbantoglu (2016), “Lime pile techniques for the improvement of clay soils”, “Canadian Geotechnical Journal”, pg: 1-9.

[3] Aref al-Swaidani, Ibrahim Hammoud, Ayman Meziab (2016), “Effect of adding natural pozzolana on geotechnical properties of lime-stabilized clayey soil”, “Journal of Rock Mechanics and Geotechnical Engineering”, Vol-8, pg:714-725.

[4] Bhuvaneshwari S, Thyagaraj T, Robinson R.G, Gandhi, S.R (2010), “Alternative Technique to Induce Faster Lime Stabilization Reaction in Deeper Expansive Strata “Indian Geotechnical Conference – 2010”, pg:609-612.

[5] D. I Boardman, S. Glendinning and C. D. F. Rogers (2001), “Development of stabilisation and solidification in limeclay mixes”, Vol-6, pg:533-543

[6] Eduardo Garzon, Manuel Cano, Brendan C.O Kelly, Pedro J. Sanchez-Soto (2016), "Effect of lime on stabilization of phyllite clays", "Applied Clay Science".

[7] F G Bell (1996), "Lime stabilization of clay minerals and soils", "Engineering geology", Vol-42, pg: 223-237.

[8] Habiba Afrin (2017), "A Review on Different Types Soil Stabilization Techniques", "International Journal of Transportation Engineering and Technology", Vol-3, pg:19-24.

[9] Innocent Kafodya, F. Okonta (2018), "Effects of natural fiber inclusions and pre-compression on the strength properties of lime-fly ash stabilised soil", "Construction and Building Materials", Vol-170, pg: 737-746.

[10] Jun-Jie Zheng, Sari W. Abusharar, Xian-Zhi Wang (2008), "Three-dimensional nonlinear finite element modeling of composite foundation formed by CFG–lime piles", "Computers and Geotechnics", Vol-35, pg:637-643.

[11] M. Yıldız, A.S. Sogancı (2012), "Effect of freezing and thawing on strength and permeability of lime-stabilized clays", Vol-4, pg: 1013-1017.

[12] Mahdi Keramatikerman, Amin Chegenizadeh, Hamid Nikraz (2016), "Effect of GGBFS and lime binders on the engineering properties of clay", "Applied Clay Science", Vol-132, pg: 722-730.

[13] Rajasekaran G and Narasimha Rao, (1996), "Lime migration studies on marine clay", "Ocean Engineering", "Vol-23, pg-325-355.

[14] Rao, S.M. and Venkataswamy B.V (2002), "Lime pile treatment of black cotton soils", "Ground Improvement", Vol-6 (2),pg: 85-93.

[15] Singh S. P., Roy N. &Sangita S. , (2016), "Strength and hydraulic conductivity of sedimented ash deposits treated with lime column", "International Journal of Geotechnical Engineering", pg-1-8

[16] SoheilSoheilJahandari, Mohammad Saberian, FarzadZivari, Jie Li, MojtabaGhasemi&Ramin Vali, (2017), "Experimental study of the effects of curing time on geotechnical properties of stabilized clay with lime and geogrid", "International Journal of Geotechnical Engineering", pg-1-12.

[17] Stefan Larsson, MirjaRothhämel, Gunnar Jacks (2009), "A laboratory study on strength loss in kaolin surrounding lime–cement columns", "An International Journal on clay and clay minerals" (ELSEVIER), Vol-44, pg-116-126.

[18] Sudeep Kumar Chand and ChillaraSubbarao, (2007), "In-Place Stabilization of Pond Ash Deposits by Hydrated Lime Columns", "Journal of Geotechnical and Geoenvironmental Engineering", Vol-133, pg-1609- 1616.

[19] Thyagaraj T., Sudhakar M. Rao, Sai Suresh P., and U.Salini, (2012),"Laboratory Studies on Stabilization of an Expansive Soil by Lime Precipitation Technique", "Journal Of Materials In Civil Engineering", Vol-24, pg1067-1075.

[20] TS. Umesha, S.V.Dinesh and P.V.Sivapullaiah (2013), "Lime to improve the unconfined compressive strength of acid contaminated soil", " International Journal Of Geology", Vol- 7, pg:49-57

[21] Wanjiong Wu, Shouyun Liang, Fanyu Zhang, Xude Yan and Jianji Zhou (2014), "Feasibility analysis of loess slope improved by lime pile", "Landslides science for a safer geoenvironment, Springer international publishing Switzerland", Vol-2.

[22] Z. Metelkova, J. Bohac , R. Prikryl , I. Sedlarova(2012), "Maturation of loess treated with variable lime admixture: Pore space textural evolution and related phase changes", "Applied Clay Science", Vol- 61, Pg:37- 43.