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A Comparative Study on Geo-Technical Characteristics of Sedimented and Compacted Fly Ash Bed Treated with Lime Column

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Abstract—*This paper highlights the effect of lime column in improving the geotechnical characteristics of sedimented and compacted fly ash. In this experimental investigation, large scale laboratory models of sediment and compacted fly ash beds were prepared with a centrally installed lime column simulating a field condition as closely as possible. After the curing periods of 30, 90, 180 and 365 days, the undisturbed fly ash specimens were collected from different radial distances and depths to study the improvement in various properties such as water content, dry density, unconfined compressive strength, and hydraulic conductivity. From the test results, it was found that lime column treatment is an effective means of increasing the unconfined compressive strength and reducing hydraulic conductivity of fly ash deposits along with modifying other geotechnical parameters including water content and density. A comparative study showed that the compressive strength and dry density of stabilized fly ash specimens collected from compacted fly ash are much higher than that of sediment fly ash bed whereas the hydraulic conductivity value was found to be less in the samples collected from the compacted fly ash bed than that of sedimented fly ash beds.*

1. INTRODUCTION

Coal based thermal power plants (TPPs) has been the backbone of a country due to its major contribution in electricity generation for the developmental purposes. With a stock of 70 billion tonnes fossil fuel reserve, majority of TPPs (84%) are run on coal. About 260 million tonnes (MT) of coal (65% of annual coal produced in India) is being used by TPPs which ultimately results in generation of enormous quantity of fly ash in the country. With the increase in generation of fly ash, its disposal has become a major issue for thermal power plants as it creates a lot of problems like shortage of usable land, increase in disposal cost, leaching of noxious heavy metals and dusting of atmospheric air. In order to get rid of disposal and dusting problem, this waste material is being used in several construction processes such as structural fills for low lying areas, embankment and subgrade for highways, backfill in retaining structures, mine stowing etc. as a replacement to conventional earth material. However, unstabilized fly ash is not suitable for construction works due to low bearing capacity and high compressibility. So in order to transform it into a promising construction material, suitable stabilization method should be adopted so that it can be used in various construction processes. In-situ stabilization of pond ash is an attractive idea to bring about improvement in the geotechnical properties. Out of several techniques, lime column treatment seems to be the best alternative for in-situ stabilization pond ash as it is less time consuming as well as cost-effective. A good number of literatures are available on successful application of lime column in stabilizing the soft soil. For instance, Barnes et al. [1] presented both laboratory and field test results of in-place stabilization of waste phosphatic clays using lime column. Results of their study showed a significant increase in shear strength in the stabilized clay specimens. Ghosh and Subbarao [3] modified class F fly ash with lime as well as combination of lime and gypsum and found a significant reduction in hydraulic conductivity with an increase in the curing period. Gupta et al. [6] presented the results of field trials for improvement of soft soils. Lime to water ratio of 30% was applied to study the efficacy of lime column in improving soft soil. The embankment made with black cotton soil was modified with lime columns and pressure injection of lime slurry and found that both techniques resulted in significant improvement in strength and settlement characteristics. Ghosh and Subbarao [4] studied the microstructural developments of a low-lime fly ash modified with 6 and 10% lime and 1% gypsum through X-ray diffraction, differential thermal analysis, scanning electron microscopy, and energy-dispersive X-ray microanalysis tests to gain information on the fly ash- Hardianto and Ericson [7] successfully used lime column in stabilizing phosphatic clays ponds. The in-situ test results show that there is a reduction in plasticity as well as permeability and increase in strength, through hydration and pozzolanic reaction and found a substantial change in strength gain and reduction in hydraulic conductivity. Chand and Subbarao [2] reported the effectiveness of in-place treatment of an ash deposit by hydrated lime column. Ghosh and Subbarao [5] studied shear strength characteristics of a low lime class F fly ash modified with lime alone or in combination with gypsum and found a significant gain in unconfined compressive strength. Kishan et al. [8] found a reduced value of hydraulic conductivity in fly ash due to addition of lime and/or gypsum with increase in curing period.

Scanning thorough the previous research works; it is perceived a limited attempt has been made to study the efficacy of lime column in improving the geo-technical characteristics of fly ash. So in this experimental investigation, an effort has been made to study the efficacy of lime column in improving various properties of fly ash such as water content, dry density, unconfined compressive strength, and hydraulic conductivity by preparing large scale laboratory models.

2. MATERIALS

2.1 Pond Ash

The pond ash used in the experimental work was procured from an ash pond at Rourkela steel plant, Rourkela. The major constituents of pond ash are silica, alumina and iron. Calcium oxide present in the fly ash is 3.2%. So, according to ASTM specification C 618-89 (1992), this ash belongs to a Class F category.

2.2 Lime

The commercially available superior grade quick lime was used to prepare lime column. The purity of lime is 90.2 %.

3. METHODOLOGY

3.1 Preparation of Sediment and Compacted Fly Ash Beds

Figure. 1 shows the test set up for sedimentation of ash slurry which consists of a large circular galvanized iron tank of 105cm diameter and 120cm height open at the top with a drainage arrangement at the base. About 1 tonne of fly ash sample was used and the amount of water required for the flow-able fly ash slurry was determined from stepby-step water addition, and mixing of fly ash. The optimum moisture content without bleeding of water from fly ash was based on eye judgment and it was found to be 75%. The slurry was prepared at this moisture content and placed in the tank. Before placing slurry in the test tank, a cylindrical steel casing of 10cm dia and 100cm height wrapped with fiber mesh of small aperture was placed at the middle of test tank. In addition to this, fly ash beds were also prepared at MDD and OMC value. For this about 1 ton of fly ash sample was taken and compacted to maximum dry density (1.16g/cc) at optimum moisture content (38.7%). After mixing, the sample was placed in the tank by 10 equal layers and tamped with a large hammer so that the compacted fly ash sample could be placed uniformly throughout the tank. Similar arrangements were also made here for placing the lime column.

3.2 Installation of Lime Column

After the elapse of two months, the lime column was installed at the center of the ash deposits in the test tank. The quantity of lime required for installing the lime column was 6.8kg.

3.3 Sampling Program

The samples were collected from various radial distances such as1 5cm, 25 cm, 35cm, and 45cm as well as depths like 10cm, 30cm, 50cm, 70cm, and 90cm after 30, 90, 180 and 365 days of installation of the lime column and various properties such as water content, dry density, unconfined compressive strength, and hydraulic conductivity were determined. The details of sampling locations for are presented in (Figure 2&3).

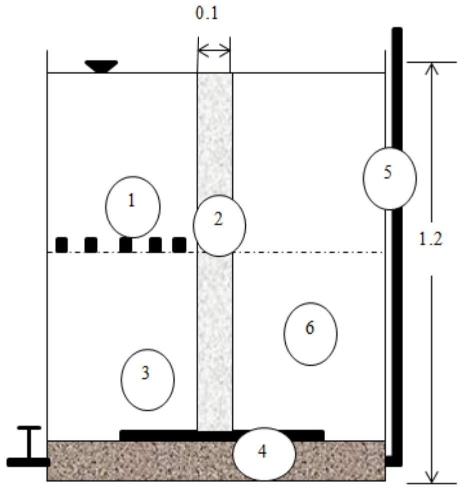

Figure 1: Details of test tank and its components

1-Temperature sensors, 2-Lime column,

3-Base plate, 4-Sandbed, 5-Stand pipe, 6-Pond ash bed

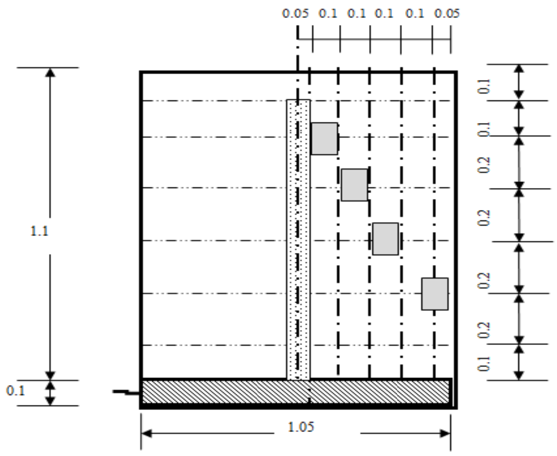

Figure 2: Elevation of the test tank showing locations for collection of samples for determination of hydraulic conductivity

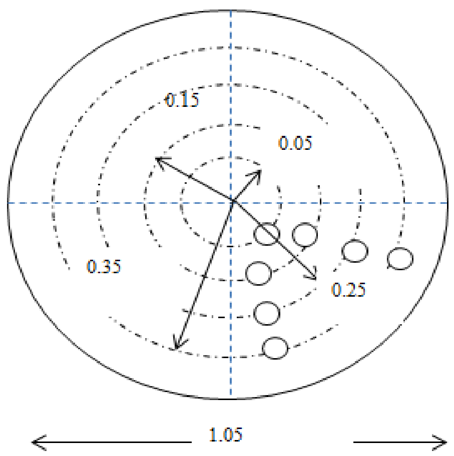

Figure 3: Plan of the test tank showing locations for collection of samples for determination of hydraulic conductivity
All dimensions are in mm

4. RESULT AND DISCUSSION

4.1 Water Content

Figure 4 and 5 represent the variation of water content with radial distance (RD) as well as depth for sedimented and compacted fly ash beds respectively. From the figures it is observed that water content is less at the locations near to the lime column. With increase in radial distance, the same value increases. This is due to the higher concentration of lime at the location near to the lime column and migration of lime in downward direction which participate in pozzolanic reaction. On the other hand, water holding capacity of the pond ash deposits decreases with increase in depth. At greater depths, the overburden pressure becomes higher, causing more consolidation, thereby resulting in lower water content.

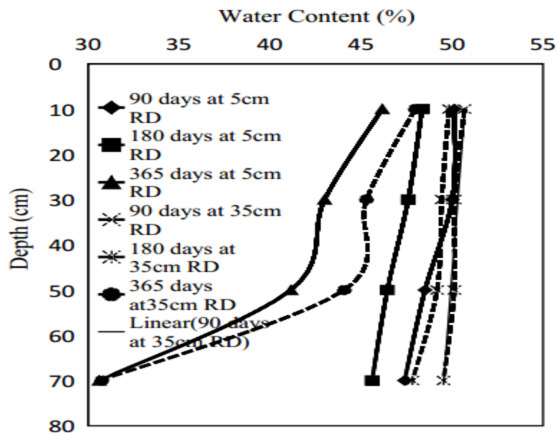

Figure 4: Variation of water content with depth on different days of curing for sedimented fly ash bed

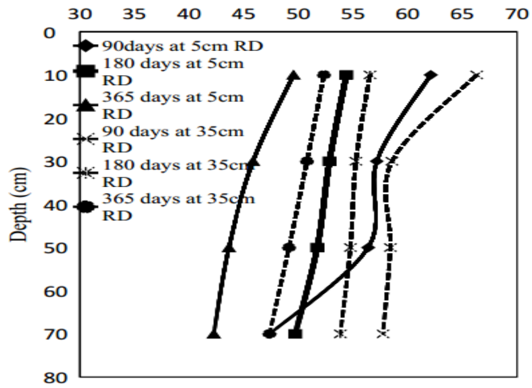

Figure 5: Variation of water content with depth on different days of curing for compacted fly ash bed

A comprarative study (Fig. 6) shows that water holding capacity of sediment fly ash bed is less than the water holding capacity of compacted fly ash bed.

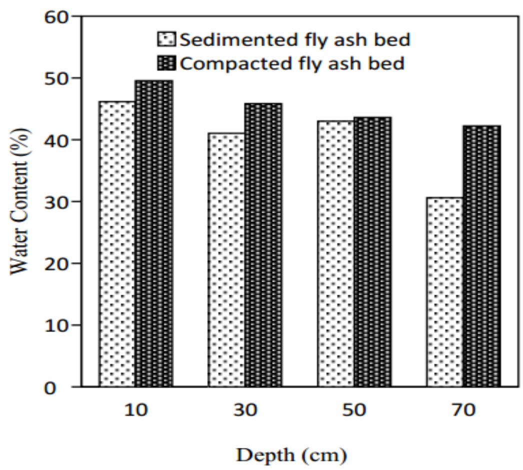

Figure 6. Variation of water content with depth in the specimens collected from 5cm radial distance in the ash beds on 365 days curing

4.2 Density

The variation of dry density with radial distance at different curing periods for sedimented and compacted fly ash bed is shown in (Fig. 7& 8) respectively.

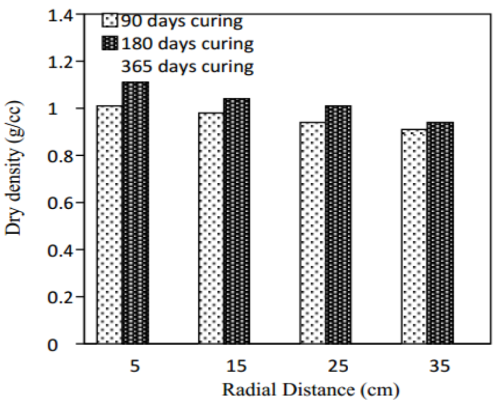

Figure 7: Variation of dry density with radial distance at 50cm depth for sedimented fly ash bed

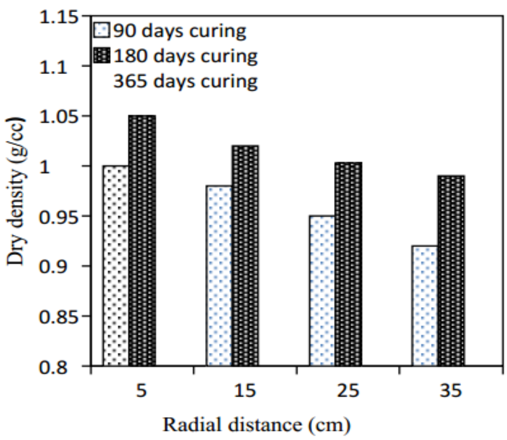

Figure 8: Variation of dry density with radial distance at 50cm depth for compacted fly ash bed

It is observed that the dry density is more in the sample collected near to the lime column and with increase in radial distance the dry density decreases. On the other hand, with increase in depth, the dry density increases. This is due to the higher concentration of lime at the location near to the lime column and migration of lime in downward direction which participate in pozzolanic reaction. The dry density of fly ash slurry is lower at top portion due to reduction in the confinement pressure occurs withless surcharge and higher water content. In addition to this, with increase in curing period, the dry density increases .This confirms that with increase in curing period the pozzolanic reaction becomes even stronger. A comparative study (Fig. 9) in the samples collected in the sedimented and compacted fly ash beds shows that the dry density ofsamples collected on 365 days curing is more in case of compacted fly ash bed . This may be due to the presence of dense layer in case of compacted fly ash bed and loose material in case of sedimented fly ash bed.

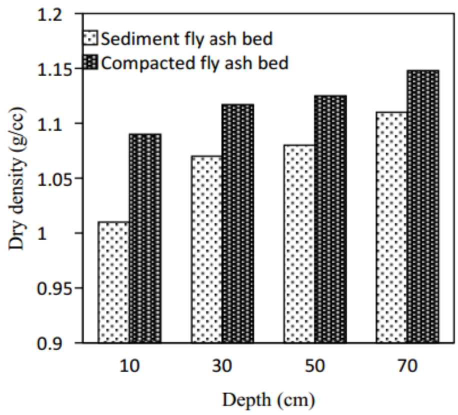

Figure 9: Variation of dry density with depth in the specimens collected from 5cm radial distance in the ash beds on 365 days curing

4.3 Unconfined Compressive Strength

The variation of unconfined compressive strength with with depth at different curing periods for sedimented and compacted fly ash bed is shown in (Fig. 10 and 11). From the test results, it is found that the the UCS value is higher in the sample collected near to the lime column as compared to the specimen collected at a greater radial distance. The same follow an increasing trend with increase in depth from the top surface of the fly ash bed. This is due to the presence of higher concentration of lime at the location adjacent to the lime column which takes part in pozzolanic reaction and results in formation of more amount of C-S-H gel near the lime column. It is also observed from that as the curing period increases, significant increase in UCS value occurs in all the depths of sediment pond ash deposit. This indicates that the hydration reaction continues with time for a considerable curing period, generating more amount of hydration products and hence increase in strength.

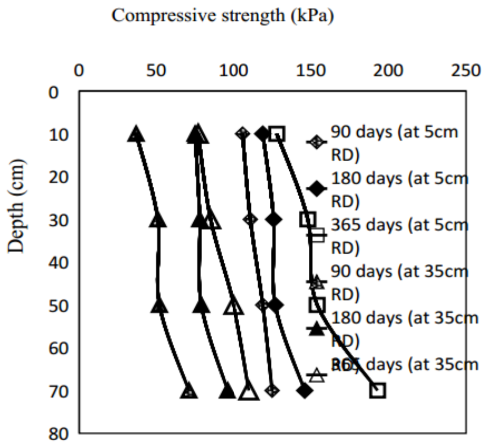

Figure 10: Variation of UCS with depth at different curing periods for sedimented fly ash bed

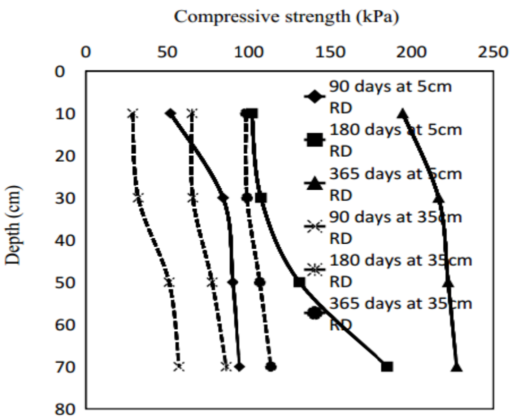

Figure 11: Variation of UCS with depth at different curing periods for compacted fly ash bed

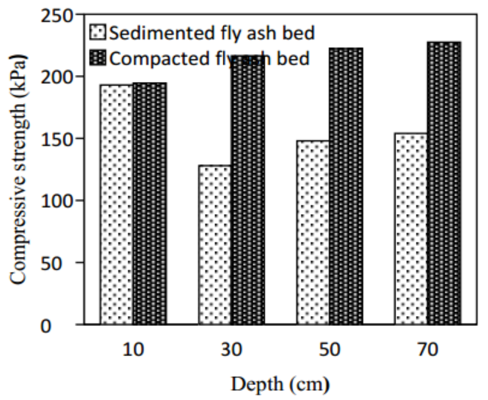

Figure 12: Variation of UCS with depth in the specimens collected from 5cm radial distance in the ash beds on 365 days curing

A comparactive study (Fig. 12) shows that the UCS value is more in the samples collected from compacted fly ash bed than that of sedimented fly ash bed. This is due to the presence of more dense layer in case of compacted fly ash bed than that of sedimented pond ash bed which leads to the increase in strength.

4.4 Hydraulic Conductivity (k)

From the permeability test results (Fig. 13&14), it is found that the hydraulic conductivity values of the specimens follow a decreasing trend with increase in depth from the top surface of the fly ash bed and also a reduced value is obtained in the samples collected adjacent to the lime column. This is due to the distribution of migrated lime over a wider area. As there is much concentration of lime near the at the location near to the lime column, so hydraulic conductivity is lesser for the samples collected adjacent to the column whereas the hydraulic conductivity is more for the samples collected at a remote area from the lime column. The reduced value of hydraulic conductivity is due to the participation of lime in pozzolanic reaction and formation of hydration products like C-S-H gel which causes reduction of void space and in the interconnectivity of pore channel. The test results show that hydraulic conductivity at depth of 10cm is less than that of 90. This indicates the presence of finer size particles on the top layer and coarser size at the bottom layer. This higher concentration of lime in pore water results in formation of more hydration products thus reducing the hydraulic conductivity of the ash bed. It is also observed that as the curing period increases, significant reduction in hydraulic conductivity occurs in all the depths of sediment pond ash deposit. This indicates that the hydration reaction continues with time for a considerable curing period, generating more amount of hydration products and hence reduction in hydraulic conductivity.

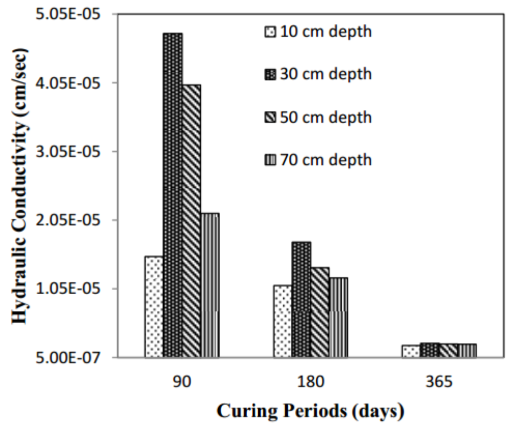

Figure 13: Variation of hydraulic conductivity with curing periods at different depths

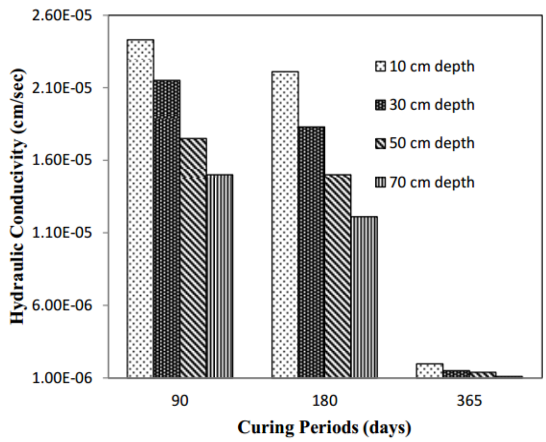

Figure 14: Variation of hydraulic conductivity with curing periods at different depths

A comparative study (Fig. 15) shows that the hydraulic conductivity in the samples collected from compacted fly ash bed is less than that of sedimented fly ash bed. This is due to the presence of more dense layer in case of compacted fly ash bed than that of sedimented pond ash bed which leads to the reduction of voids and hence, reduction in hydraulic conductivity

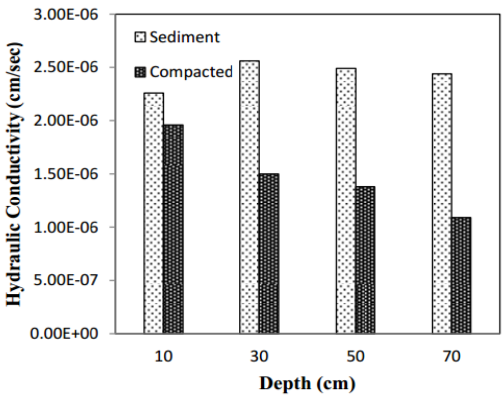

Figure 15: Variation of hydraulic conductivity with depth in the specimens collected from 5cm radial distance in the ash beds on 365 days curing

5. CONCLUSIONS

Based on the experimental investigation the following conclusions can be drawn

(1) The dry density and UCS values were found to be increased with increase in depth and curing period. However, the same is found to be reduced with increase in radial distance from the lime column.

(2) The water content and hydraulic conductivity values were found to be decreased with increase in depth and curing period. However the same is found to be more with increase in radial distance from the lime column.

(3) A comparative study shows that the dry density and strength of compacted fly ash bed is much higher than the sedimented fly ash bed whereas the hydraulic conductivity value of the samples collected from compacted fly ash bed is less than that of sedimented fly ash bed.

From the experimental investigation, the in-place stabilization by lime column technique has been found to be effective in increasing the unconfined compressive strength and reducing hydraulic conductivity of pond ash deposits in addition to modifying other geotechnical parameters including water content, density.

6. ACKNOWLEDGEMENTS

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