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Study on the Characterization and Classification of Fly Ash Samples Obtained Locally

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ABSTRACT

The excavation of soil for various construction purposes, such as road construction, earth dam construction, soil stabilization, and backfill material, raises significant concerns as it takes thousands of years for natural topsoil to form. This excavation often leads to deforestation, which negatively impacts biodiversity. To address these issues, industrial waste materials like fly ash and slag can be effectively utilized as alternatives to natural soil. The sustainable utilization of fly ash is particularly important for thermal power stations, as large-scale usage in geotechnical construction projects can reduce the challenges associated with its disposal.

However, since the properties of fly ash can vary depending on its source, it is crucial to assess the variability of these properties before using fly ash as a construction material. In this study, four different fly ashes from local thermal power plants were examined through various geotechnical laboratory experiments to determine their properties. The results obtained from these experiments were then compared with existing literature on fly ash properties.

The study identified the optimum lime content required for achieving a desirable unconfined compressive strength, which was found to depend on the specific source of fly ash. Using an existing classification scheme for fly ash, it was observed that all four fly ashes belonged to the same class. However, significant variations in their properties were noted. The experimental results also indicated that the strength, cohesion, and friction of fly ash could be improved by stabilizing it with lime. Nevertheless, the strength values and the degree of improvement differed noticeably among the four fly ashes. Therefore, it is necessary to consider an alternative classification scheme for fly ash when utilizing it as a fill and embankment material in order to ensure its effective utilization.

KEYWORDS: *Concrete, Fly Ash, Admixture, Soil Stabilization.*

1. INTRODUCTION

Fly ash exhibits similarities to volcanic ash, which was historically used as a hydraulic cement near the town of Pozzuoli in Italy. This led to the term "pozzolan" being coined, referring to one of the world's best pozzolans.

In the present day, fly ash is predominantly generated from coal-fired power plants. As industrialization has progressed rapidly, there has been a significant increase in fly ash production. Power plants pulverize coal into fine powder before burning it. The mineral residue resulting from coal combustion is collected from exhaust gases using an electrostatic precipitator for subsequent utilization. However, the major challenge associated with fly ash production is its safe disposal and management. Industrial waste possesses complex characteristics and compositions, necessitating proper treatment and disposal to prevent negative impacts on the environment and society. Failure to address these concerns can lead to soil and water contamination, ultimately disrupting the ecological system.

Micro-sized fly ash primarily consists of silica, alumina, and iron. The spherical shape of fly ash particles facilitates easy blending and flow, making it suitable for various mixtures. Capillarity is one of the advantageous properties of fly ash when used as an admixture in concrete. Fly ash exhibits both amorphous and crystalline mineral characteristics. The properties of fly ash exhibit temporal variation, including complex changes in chemical, physical, and geotechnical properties. Therefore, it is essential to study the properties of fly ash from different sources to better understand its behavior and ensure effective utilization.

2. UTILIZATION OF FLY ASH

Utilization of fly ash in particular, can be broadly grouped into three categories.

- The low-value uses include building roads, embankments and dams, backfilling mines, structural fills, soil stabilization and ash dykes, among others.
- Pozzolana cement, cellular cement, bricks/blocks, grouting, fly ash concrete, prefabricated construction blocks, light weight aggregate, grouting, soil amendment agents, etc. are among the medium value utilisations.
- The High Value Utilisations include metal recovery, magnetite extraction, acid refractory bricks, the ceramics sector, floor and wall tiles, fly ash paints and deodorants, among other things.

3. CLASSIFICATION OF FLY ASH

Fly ash is the term used for the finely pulverized fuel ash extracted from flue gases through an electrostatic precipitator. It is the finest among the three types of ash, which include pond ash, bottom ash, and fly ash. Fly ash is collected from the emissions of high stack chimneys in power plants. It mainly consists of non-combustible particulate matter, along with some unburned carbon. The particles in fly ash are typically of silt size.

To classify fly ash based on its lime reactivity, four different types are recognized. These types are determined through lime reactivity tests and help in assessing the suitability and performance of fly ash in various applications. The classification of fly ash into different types is important for understanding its characteristics and utilizing it effectively in different engineering and construction activities:

- Cementitious fly ash
- Cementitious and pozzolanic fly
- Pozzolanic fly ash
- Non-pozzolanic fly ash

4. LITERATURE REVIEW

Several studies have been conducted on fly ash, revealing various insights into its properties and behavior:

Sherwood and Ryley (1970) found that the lime fraction present in fly ash contributes to its self-hardening properties in the form of calcium oxide.

Gray and Lin (1972) attributed the variation in specific gravity of fly ashes to factors such as particle shape, size, gradation, and chemical composition.

Mclaren and Digioia (1987) observed that fly ash exerts low earth pressures due to its lower specific gravity, making it suitable for backfill material in embankments and weak foundation soils.

Martinet al. (1990) stated that fly ash exhibits apparent cohesion values in moist and partially saturated conditions due to capillary rise but is not suitable for long-term stability. Shear strength is a more significant criterion for stability.

Yudbir and Honjo (1991) found that the lime content of fly ash affects its self-hardening properties, which depend on the availability of free lime and carbon content in the samples.

Wesche (1991) determined that the loss of ignition percentage in fly ash indicates the presence of unburnt carbon.

Rajasekhar (1995) identified that fly ash primarily consists of cenospheres and paleospheres, contributing to its low specific gravity due to the presence of entrapped air within spherical particles.

Singh (1996) established a correlation between the unconfined compressive strength of fly ash and its free lime content and apparent cohesion.

Singh and Panda (1996) showed that the shear strength of freshly compacted fly ash depends on the internal friction angle, which, in turn, relies on the maximum dry density of the fly ash sample.

N.S. Pandian (1998) highlighted the favorable properties of fly ash, including low specific gravity, good drainage, ease of compaction, and good frictional properties, making it suitable for various geotechnical engineering applications.

Pandian and Balasubramonian (1999) noted that the coefficient of permeability of fly ash depends on its degree of compaction, grain size distribution, and pozzolanic activity.

Erdal Cokca (2001) emphasized that the hollow spherical cells in fly ash provide bivalent and trivalent cations that promote the dispersion of clay minerals.

Sridharan and Pandian (2001) Compacted fly ash tested in unsoaked condition , have higher CBR values ,then soaked condition of most of the fine grained soils. Such higher CBR value is due to capillary force, that exist in the partly saturated state.

Das and Kalidas (2002) The specific surfaces of fly ashes , subjected to grain size in ESP hoppers may vary considerably.

Trivedi and Sud (2004) The specific gravity increases, with increase in fineness and finest fly ash has maximum specific gravity. Table shows that, some of variation in specific gravities.

Das and Yudhbir (2005) stated that the geotechnical properties of fly ash are influenced by lime content, iron content, loss on ignition, morphology, and mineralogy structure.

Prakash and Sridharan(2006) If more than 50% of fines (i.e., fraction of size finer than 75mm) belongs to either the coarse silt size category or the medium silt size category or (fine silt+clay) size category , then the ash is represented as MLN or MIN or MHN respectively.

These studies, along with others, have contributed to our understanding of fly ash and its potential applications in geotechnical engineering.

5. EXPERIMENTAL SETUP AND PROCEDURE

The present study focuses on the characterization of fly ash using various experimental methods. These methods aim to investigate and understand the morphological, chemical, physical, and geotechnical properties of fly ash. The characterization of these properties is crucial in determining the suitability of fly ash for different geotechnical applications. The experimental methods employed in this study are described in detail below:

- Chemical Properties Mineralogy
- Chemical Composition
- X-Ray Diffraction
- Scanning Electron Microscope Studies
- pH Of Coal Ashes
- Lime Reactivity
- Physical Properties
- Engineering Properties

6. CONCLUSIONS

Based on the present project work, the following conclusions can be drawn:

- The fly ashes analyzed in this study belong to Class F fly ash with a CaO content of less than 10%.
- Different fly ashes exhibit variations in their morphological characteristics. NALCO fly ash contains cenospheres with small agglomerates, TTPS fly ash contains cenospheres with single cells without agglomerates, NTPC fly ash contains both cenospheres and plerospheres, and Kalunga fly ash contains sub-rounded porous grains, irregular agglomerates, and irregular porous grains of unburnt carbon.
- The lime reactivity of the fly ashes is influenced by the presence of reactive silica. The lime reactivity follows the order: NALCO > TTPS > NTPC > Kalunga.
- The specific gravity of the fly ashes obtained in this study is as follows: Kalunga (2.41), NALCO (2.21), TTPS (2.13), and NTPC (2.04). The presence of iron particles can increase the specific gravity, but overall, fly ashes have relatively low specific gravity due to the abundance of cenospheres.
- The grain size distribution of the fly ashes is uniformly graded with silty particles. The coefficient of uniformity (Cu) decreases with an increase in the fineness of the fly ash.
- The free swell ratio of the fly ashes is as follows: NALCO (-35.53%), NTPC (-31.34%), TTPS (-30.88%), and Kalunga (-25.00%).
- The specific surface area of the fly ashes follows the order: Kalunga > NALCO > TTPS > NTPC.
- The fly ashes analyzed in this study belong to the MLN-MIN category.
- Lime fixation points for Kalunga and NTPC fly ashes occur at 6% lime content, while for NALCO and TTPS fly ashes, it occurs at 7% lime content. The unconfined compressive strength (UCS) increases with an increase in lime content up to the lime fixation point.
- Fly ashes compacted on the dry side of optimum moisture content exhibit higher strength compared to those compacted on the wet side.
- From the triaxial shear test, the shear parameter values for the fly ashes follow the order: Kalunga > NTPC > TTPS > NALCO. Fly ash demonstrates shear strength primarily through internal friction and exhibits some apparent cohesion.
- The CBR values of the fly ashes under soaked conditions decrease in the following order: Kalunga > NALCO > NTPC > TTPS. The low CBR values under soaked conditions are due to the destruction of capillary forces. The degree of saturation significantly affects the CBR value of compacted fly ash.

- The degree of dispersion follows the order: NTPC > TTPS > NALCO > Kalunga for the fly ashes analyzed in this study.
- The low specific gravity, good drainage characteristics, ease of compaction, and favorable frictional properties make fly ash suitable for construction applications such as embankments, roads, and fill behind retaining structures. It also exhibits pozzolanic activity.
- In summary, the present study provides insights into the properties and behavior of fly ash, indicating its potential as a useful material in various geotechnical engineering applications.

REFERENCES

1. Aarathi Prasad and Sujatha Bai, K. (1999), “Lime reactivity in some Indian coal ashes”, *Proc. Nat. Seminar on Fly Ash Characterization and its Geotechnical Applications*, Bangalore, India, pp:15-20
2. Alam J., Akhtar M.N.,(2011) “Fly ash utilization in different sectors in Indian scenario”. Issue 1, ISSN 2249-6149.
3. Alok Ranjan, Guru Vittal, U.K., Satander Kumar and Murthy, A.V.S.R. (1998), “Some aspects of fly ash characterization and utilization”, *Proc. Inter. Conf. on Fly ash Disposal and Utilization, CBIP*, New Delhi, VIII-3, pp:14-19
4. ASTM C 618-94a (1995), Standard Specifications for coal ash and raw or calcined natural pozzolan for use as a mineral admixture in Portland cement concrete, *Annual book of ASTM standards*, Vol. 104.02, ASTM, Philadelphia
5. Bhanumathidas, N. and Kalidas, n.(2002), Fly ash for Sustainable Development, *Ark Communication*, Chennai.
6. C. Rajasekhar(1995). “Retention and permeability characteristics of clays and clay fly ash systems subjected to flow of contaminants”, *Ph.D. Thesis*, Indian Istitute of Science, Bangolore.
7. Das S., Yudhbir., Oct. (2005), Geotechnical characterization of some Indian Fly Ashes. *Journal of materials on civil engineering*. pp:544-552.
8. Das. S.K., Yudhbir(2006), “Geotechnical properties of low calcium and high calcium flyash”. *Geotechnical and Geological engineering* 24, pp:249-263.
9. Gray D. H.and Lin Y. K.(1972). “Engineering properties of compacted fly ash.” *J. Soil Mech. Foundation Engng, ASCE*, 98, 361–380.
10. Hart, B.R., Powell, M.A., Sahu, K.C., Tripathy, S. and Fyfe, W.S. (1991), “Mineralogic and element association of coals from the Gevra mine, Korba coal field, Madhya Pradesh, India”, *Proc. Inter. Conf. on Environmental Impact of Coal Utilization*, IIT Bombay, India, pp:39-58.
11. Lambe, T.W. and Whitman, R.V.(1979), Soil mechanics, SI version, *John Wiley and sons*, Inc., NewYork.
12. Leonards, G.A. and Bailey, B. (1982), “Pulverized coal ash as structural fill”, *J.Geotech.Engg. Div. ASCE*, Vol.108, No. GT 4,pp:517-531.
13. McLaren R.J. and Digioia A.M.(1987). “ The typical engineering properties of fly ash.” *Proc., Conf on Geotechnical Practice for Waste Disposal, ASCE*, New York, pp:683-697
14. N.S Pandian, C. Rajasekhar and A. Sridharan (1998), “Studies on the specific gravity of some Indian coal coal ashes”, *J.Testing Evaluation, ASTM*, 26, pp:177-186.
15. Pandian, N.S.(2004). “Fly ash characterization with reference to geotechnical applications.” *J.Indian Inst. Sci*., 84, pp:189-216.

16. Singh S.R. and Panda, A.P (1996), “Utilization of fly ash in geotechnical construction”, *Proc. Indian Geotechnical Conf.*, Madras, Vol. 1, pp:547-550.

17. Sridharan, A. and Prakash, K.(2000), “ Classification procedures for expansive soils”, *Geotechnical engineering, Proc. Inst. Civil Engg.(London)*, Vol.143, pp:235-240.

18. Sridharan, A., Pandian, N.S. and Srinivasa Rao, P. (1998),”Shear strength characteristics of some Indian fly ashes”, *Ground Improvement*, Vol. 2, No. 3, pp:141-146.

19. Sridharan, A., Pandian, N.S., Srinivas, S. and Subramanya Prasad, P. (2001), Vol. 1:Physical Prpperties of Indian Coal Ashes, *Technical report of task force on Characterization of fly ash submitted to Technology Mission-Fly ash Disposal and Utilization, Dept. of Science and Technology*, Govt. of India.

20. Sridharan, A., Pandian, N.S., Subramanya Prasad, P. and Srinivas, S. (2001), Vol.2: Chemical Properties of Indian Coal Ashes, *Technical report of task force on Characterization of fly ash submitted to Technology Mission-Fly Ash Disposal and Utilization, Dept. of Science and Technology*, Govt. of India.

21. Sridharan, A., Prakash, K., (2006), “ A Geotechnical classification system for coal ashes”, Geotechnical Engineering , Proc. Inst . Civil Engg.(London), Vol. 159, pp:91-98.

22. Sridharan, A., Prakash, K., (2007), “Geotechnical Engineering characterization of coal Ashes. *CBS publishers Ltd*.

23. Trivedi, A. and Sud , V.K.(2004), “Collapse behavior of coal ash”, *J. Geotech. And Geoenv. Engg. ASCE*, Vol.130, No.4, pp:403-415.

24. Yudhbir and Honjo, Y.(1991), “Application of geotechnical engineering to environmental control”, Proc. 9th Asian Reg. Conf on S.M.&F.E., Bangkok, Thailand, Vol. 2, pp:431-469.