GEOTECHNICAL HARACTERIZATION OF SOILS BLENDED WITH FLY ASH

*S.UDAYA KUMAR[1], RAJIV S R[2]
[1]M. Tech Student, [2]Faculty,
Department of Civil Engineering, M V R College of Engineering and Technology
Paritala, Krishna District, Andhra Pradesh - 521180
(*Corresponding Author)

ABSTRACT: ***This paper deals with an experimental study on the use of fly ash and fly ash-based geopolymers for the stabilization of expansive soils (high and low plastic) as soil stabilizers and partial replacement of moorum (non-plastic soil). In the last decades, several traditional stabilizers such as cement and lime have been used, that cause adverse effects on environment. The carbon footprint and high energy consumption are associated with the manufacturing of these stabilizers form environmental limitations. For bulk soil stabilization of expansive soil, the consumption of these traditional binders is relatively high. Hence, the industry immensely needs new alternative binders that feature low environmental footprint without compromising soil stabilization capabilities. Fly ash-based geopolymers through alkali activation of fly ash forms a cementitious material that act as binders, as they involve useful recycling/diversion of discarded aluminosilicate industrial by-product materials. The fly ash-based geopolymer stabilized expansive soil shows significant increase in strength performance (UCS, CBR, and MR), and reduction in swelling and shrinkage behavior of soil. Based on the microstructural studies, microstructural changes of stabilized soil were observed that reflect the formation of geopolymeric gel. The optimized stabilizer dosage to achieve the maximum UCS (1606.14 kPa) was defined in terms of FAR and CD i.e., 1.5 and 22.75 (approx. 23) days. While maximum CBR performance was 40.03%, for FAR-2 and CD-27.98 (approx. 28) days. The application of fly ash-based geopolymer stabilized soil was demonstrated in terms of the design of flexible pavement for low and high-volume roads. In addition, to gain practical and economical confidence, cost analysis was carried out for stabilized soil (fly ash-based geopolymer) and comparison has been made with conventional materials. The stabilized soil for flexible pavement gives significant reduction in pavement thickness (51.68%) and the overall cost of pavement construction (10.50%).***

Key Words: Geopolymers, Stabilization, Expansive soils, fly ash.

I. INTRODUCTION

Generally, Indian road embankments, subgrades, and subbase layers of pavements are constructed using stabilized soil such as moorum, sand, etc. Moorum is nothing but soft aggregates obtained from lateritic decomposition. It has high strength characteristics, so it can be treated as a good construction material. However, the scarcity of moorum can increase the construction cost in some parts of the country. Hence, finding alternative materials for moorum or reducing the utilization, or partially replacing moorum with some other industrial by- products may save the quantity of moorum. Therefore, based on the latest suggestion of the Ministry of Roads Transport and Highway (MORTH), several types of industrial by-products are mentioned such as fly ash, rice husk ash, ground granulated blast furnace slag, steel slag, etc. can be suitable as a construction material.

In this context, the utilization of low-energy-intensive stabilizers such as cement, kiln dust, calcium carbide residue, granulated blast furnace slag, fly ash, and geopolymeric binders in soil stabilization has been studied by various authors (Ghosh et al., 2016; Murmu et al., 2019, 2020; Parhi et al., 2018b; Phummiphan et al., 2016, 2018; Rao & Ganta, 2015) in recent years. To support sustainable soil stabilization, geopolymer is an inorganic aluminosilicate material formed from the polycondensation of silica and alumina (Davidovits, 1991; Zhang et al., 2013). Therefore, a fly ash-based geopolymer could also be a better option for soil stabilization already proposed by (Zhang et al., 2013) and has become a green area for research on soil stabilization. Although a number of research works are available on the application of fly ash-based geopolymer as a building material. (Fernández-Jiménez et al., 2005; Hardjito et al., 2004; Hardjito & Rangan, 2005; Patankar et al., 2014; Patankar, 2017;
Patankar et al., 2013; Rangan, 2014; Singh, 2018; Yunsheng & Wei, 2006). However, selected studies were available on fly ash-based geopolymers and their application in soil stabilization. Stabilization of Indian expansive soil or black cotton soil by means of fly ash-based geopolymers was investigated by various authors up to a limited extent (UCS, CBR) (Bagewadi & Rakaraddi, 2015; Murmu et al., 2019, 2020; Parhi et al., 2018b; Syed et al., 2020; Thomas et al., 2018). Some studies have also been conducted on various types of soils and aluminosilicate source materials for soil stabilization using geopolymer (Hayder Hasan Abdullah, 2020; Cristelo et al., 2011, 2012, 2013; Debanath et al., 2019; Dungca & Codilla, 2018; Khadka et al., 2018; Zhen Liu et al., 2016; Phetchuay, 2015; Phummiphan et al., 2018, 2016, 2017a; Yaghoubi et al., 2018b). The contribution of the authors indicates that there is significant potential to work in this direction to develop an eco-friendly solution for various geotechnical projects.

Chemical composition of fly ash relates directly to the mineral chemistry of the parent coal and any additional fuels or additives used in the combustion or post-combustion processes. The pollution control technology that is used can also affect the chemical composition of the fly ash. Electric

generating stations burn large volumes of coal from multiple sources. Coals may be blended to maximize generation efficiency or to improve the station environmental performance. The chemistry of the fly ash is constantly tested and evaluated for specific use applications.
Some stations selectively burn specific coals or modify their additives formulation to avoid degrading the ash quality or to impart a desired fly ash chemistry and characteristics.
Geopolymers are normally synthesized by mixing source materials having alumino-silicate and the alkaline solutions. Source materials used are kaolinite, clays, zeolite, fly ash, silica fume, slag, POFA, rice-husk ash, red mud, etc. The most liquid used in geopolymerization is a combination of NaOH/KOH and sodium silicate. When any of the above source materials (for example fly ash (FA) in solid form) are mixed with alkali solutions of appropriate concentration and sodium silicate, geopolymers are formed. It has been reported by Zhuang et al. [7] that during the polymerization reaction of fly ash, the following processes may take place.
Although there is no standard method prescribed, geopolymer concrete is made in a similar way as conventional Portland cement concrete. First of all, activator solutions as given here are prepared. The required quantity of NaOH pellets is dissolved in water to have to the required concentration. For example, to prepare an 8 M NaOH solution, 320 g of NaOH pellets are dissolved in one liter of solution since the molecular weight of NaOH is 40. This solution is then mixed with the required quantity of Na2SiO3 solution to fix the ratio of alkaline activator solution as 1.5, 2.0 and 2.5. Fly ash, sand and the aggregates are first mixed together in dry state and then mixed with alkaline liquid and a small dose of the super plasticizer. Extra water may be added if needed. The fresh concrete was cast and compacted in the molds of standard size. Generally, heat-curing (60–90 °C) of geopolymer concrete is done. It assists the chemical reaction that occurs in the geopolymer paste.
Therefore, to address the gaps mentioned above, this research presents and conducts an extensive experimental investigation on the fly ash-based geopolymer for the stabilization of expansive soil. Additionally, the application of stabilized soil is presented in terms of the design of flexible pavement as per the Indian Road Congress (IRC) and the Ministry of Road Transport & Highways (MORTH) guidelines.

OBJECTIVES

Motivated by the challenges of effective utilization of fly ash in the enviro-friendly geotechnical construction industries and to find an alternative to the traditional stabilizer for sustainable construction, this research aims to use fly ash-based geopolymers for expansive soil stabilization. This research also aims to enhance the understanding and provide valuable insights into the strength behavior of fly ash-based geopolymer treated soils. The objectives of the current research are as follows:

1. To evaluate and characterize the geotechnical properties of plastic (high & low plastic) and non-plastic (moorum) soils and their blend with fly ash.

2. To evaluate and characterize the geotechnical properties of soil based on plasticity with fly ash-based geopolymer.

3. Investigate the microstructure and morphology of soil geopolymer mixtures in relation to mix variables and curing conditions.

II. MATERIALS USED

In this experimental program, the primary stage includes the preliminary research on selecting the raw materials.

1. Soils

In the present study, moorum and expansive soil (high and low plastic soils) have been used. All soil samples were collected from a depth of 1 m below the ground surface at different locations as described in the subsequent sections.

2 .Moorum

The locally available moorum was collected from the NIT Raipur campus, Raipur, Chhattisgarh, India. Moorum is a common material easily obtained in various parts of Chhattisgarh state. Moorum is considered a stabilized material for the construction of road pavement for base and sub-base courses (IRC and MoRTH). The collected moorum sample
was preliminarily dried for 2 days and particles were separated with the help of a wooden hammer.

3. Expansive Soil

The expansive soil was obtained from two different locations near Raipur city. It was transported to the laboratory for classification and strength characterization. To understand the effect of fly ash and geopolymer on the plasticity characteristics of soil, it was classified into two categories according to the Unified Soil Classification System (USCS), high plastic soil and low plastic soil. The following section discusses about these two types of soils, also further investigation was carried out on the same.
High plastic soil-High plastic soil (HPS) (LL > 50), was collected from village Amleshwar, near Raipur city, Chhattisgarh, India.
Low plastic soil-Low plastic soil (LPS) (LL < 50), was collected from Dunda village, near Raipur city, Chhattisgarh, India.
Generally, the top surface of the soil is contaminated and contains the roots of various plants. Such soils may not be suitable for laboratory experiments, so to avoid such soil, the sample has been collected at a depth of 1m, and also the locally available soil was used to construct subgrade and sub-base layers, that may not have an adequate strength performance. Hence, such soils need proper treatment for the application of construction materials as a subgrade or sub-base. The soil is transported to a laboratory for testing, preliminarily it is allowed to dry for two days and thoroughly grinded through a wooden mallet.

4 .Stabilizer - Fly ash

In this study, fly ash is used as a stabilizer for the stabilization of expansive soils and partial replacement of moorum. Fly ash has been collected from the thermal power plant of National Thermal Power Corporation and Steel Authority of India Limited (NSPCL), Bhilai, Chhattisgarh, India. As per the Central Electricity Authority, 2021, New Delhi, India, the generation of fly ash in India was about 232.56 million tons, out of which Chhattisgarh state generates 40.25 million tons which is the highest in the country. The fly ash sample was collected in plastic bags and transported to the laboratory for conducting different experiments.

5.Alkaline activator

Alkaline activators were used for the activation of fly ash to stabilize the expansive soil. The sodium hydroxide (NaOH) and sodium silicate (Na2SiO3) solutions have been used for the activation of fly ash. The sodium hydroxide was originally in pallets and collected from the local supplier, while sodium silicate was in alkaline grade liquid form and collected from Shri Saibaba Chemicals, Gujrat, India. Liquid sodium silicate consists of Na2O = 14.35% and SiO2
= 33.10% of specific gravity 1.56 (provided by the supplier). The researchers suggested a suitable concentration for NaOH between 4.5 to 18 molars (Bakri et al., 2012; Nematollahi & Sanjayan, 2014; Yaghoubi et al., 2018b). Therefore, from an economic and safety point of view, low concentrated NaOH, ie, 6 and 8 molars (M) were adopted for experimental investigations. NaOH of 6M and 8M solution was prepared just one day before casting of samples for the test by mixing 240g (NaOH molecular weight 40 g/mole*6M) and 320g (NaOH molecular weight 40 g/mole*8M) of NaOH flakes to make 1-liter solution in water respectively. As per the recommendation of Murmu et al. (2019), the ratio of Na2SiO3/NaOH
was selected as 1.5 to study the effect of activator on expansive soil fly ash composite. The liquid solution of Na2SiO3 was mixed to promote the gelation and precipitation of silicates in geopolymerization (Khale & Chaudhary, 2007). Most studies suggested that alkaline silicate induces soluble SiO2 to form monomers, leading to better microstructure and enhancing its mechanical performance (Liew et al., 2016).

Table .1 Properties of all Materials

Constituents (%)	Moorum	High Plastic Soil	Low Plastic Soil	Fly ash
Silica (SiO_2)	54.15	59.63	66.99	62.39
Alumina (Al_2O_3)	17.3	17.38	12.89	24.47
Iron Oxide (Fe_2O_3)	19.35	13.57	12.09	5.74
Calcium Oxide (CaO)	2.87	2.12	2.22	1.79
Magnesium Oxide (MgO)	1.08	1.57	1.32	0.62
Potassium (K)	4.12	4.4	2.76	2.75
Titanium (Ti)	1.14	1.33	1.73	2.25

III. EXPERIMENTAL PROGRAM

Moorum-fly ash blend

The effects of fly ash on the index properties of moorum were evaluated by conducting the Atterberg limit, specific gravity, and grain size distribution (dry sieve analysis and hydrometer analysis) for different proportions of fly ash (15%, 20%, 25%, and 30%). Strength characteristics were evaluated by performing compaction test, California bearing ratio test, and direct shear tests (DST) on all samples.
Soil samples for the modified Proctor compaction test were prepared according to IS: 2720-8 (1985) by taking oven-dried fly ash and moorum in the mixing pan with water. The maximum dry unit weight (MDU) and optimum moisture content (OMC) were evaluated for all the samples.
The CBR test samples were prepared based on the obtained MDU and OMC and tested under unsoaked and soaked conditions. Under unsoaked conditions, samples were tested immediately after preparation, whereas under soaked conditions, the samples were placed in water for at least 4 days, and then it was tested. Here, the soaked condition was subjected to soaking for 4 days and further curing for 3 and 24 days to understand the effect of water on strength. Direct shear tests were conducted as per IS code mentioned in Table 3.1. Direct shear test samples were prepared based on the basis of the MDU and OMC. The experimental investigation was carried out for moorum fly ash blends as shown in the flow chart.

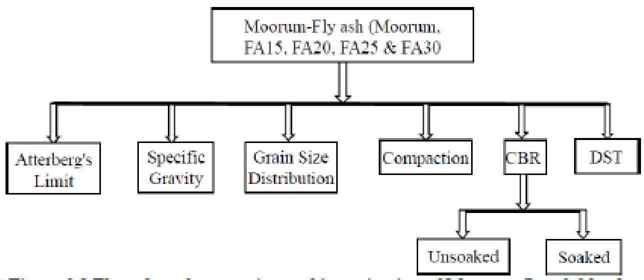

Figure 1. Flow chart for experimental investigation of Moorum-fly ash blends

Expansive soil- fly ash blend

Initially, HPS and LPS were mixed with fly ash at various proportions (10%, 15%, 20%, 25%, and 30%). The proportion of fly ash content was decided based on the available literature, e.g., Cokca (2001), Kate (2005), Trivedi et al. (2013), Mahajan and Parbat (2015). These studies suggested that the optimized percentage of soil stabilizers was in the range of 15% to 25% for soil stabilization. Strength parameters such as compaction test, unconfined compression strength tests, and California bearing ratio test were performed on the expansive soil and fly ash blends according to the relevant IS codes.

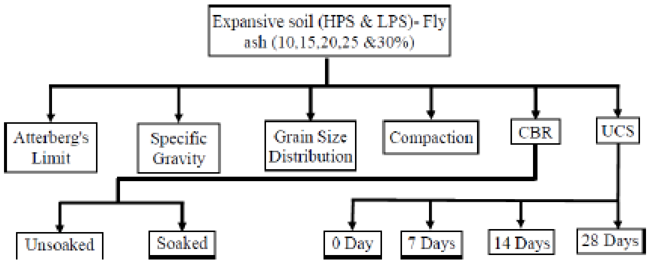

Figure 2. Flow chart for experimental investigation of Moorum-fly ash blends

IV. RESULTS AND DISCUSSION

The results obtained in this research work were presented here.

Atterberg Limits and Specific Gravity

The Atterberg limits are essential for the characterization of soils that indicates the plastic nature of the soil. Atterberg limits test carried out on HPS and LPS with different percentages of fly ash is shown in Figure 3 (a and b).
It was observed that the liquid and plastic limit of the fly ash-soil mix decreased with increase in fly ash content, which is due to the reduction of diffuse double layer of water formed around the clay particles. The general observation was that with the addition of fly ash content, the plastic limit may increase due to flocculation of the soil particles and reduction of diffuse layer owing to the presence of free lime (Sivapullaiah et al., 1996). However, in this case, the plastic limit is reduced as there is no sufficient amount of free lime to hold the particles together. The increasing amount of fly ash in mixes decreases the particle flocculation due to finer fly ash particles occupying the spaces of flocculated soils (Hakari & Puranik, 2012). Similar patterns of Atterberg limits were observed for LPS
Soil adjustment is one among generally huge for the advancement that is wide utilized regarding street asphalt and establishment development because of It improves the designing properties of soil like strength, volume depend ability and toughness. Inside the blessing examination is to pass judgment on the compaction and unconfined compressive strength of balanced out dark cotton soil abuse fine and coarse debris blends. The portion of fine and coarse debris combinations that is utilized.
The liquid limit of a soil containing substantial amounts of organic matter decreases dramatically when the soil is oven-dried before testing. A comparison of the liquid limit of a sample before and after oven-drying can, therefore, be used as a qualitative measure of the organic matter content of a soil.

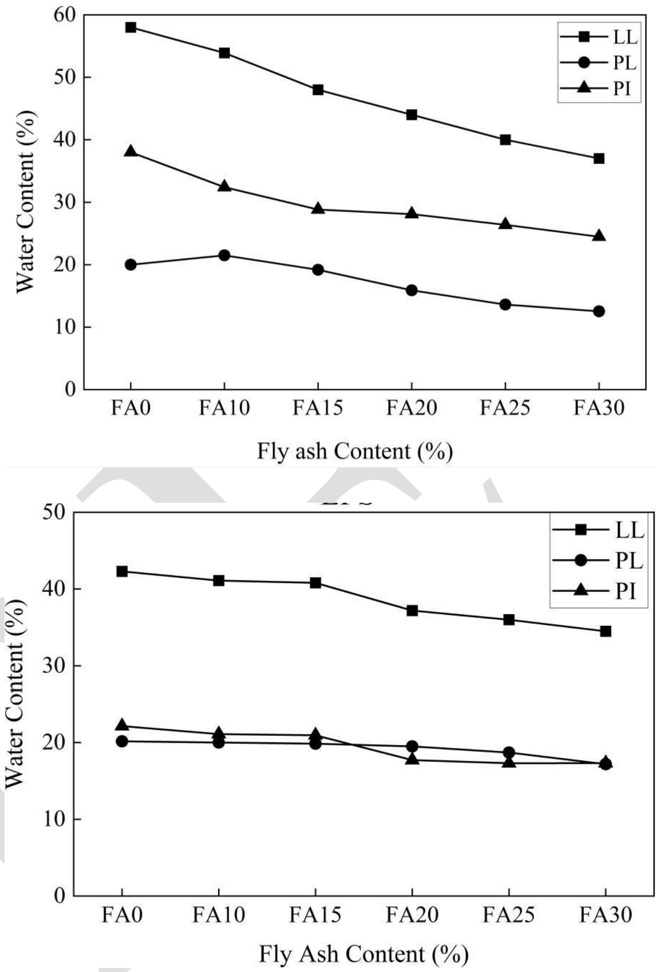

Figure 3 Atterberg limits for (a) HPS and (b) LPS

The specific gravity of HPS and LPS was performed as shown in Figure 3. It can be seen that increase in fly ash content specific gravity of the soil mix reduces. The reason for the reduction in specific gravity was due to the light weight of fly ash.

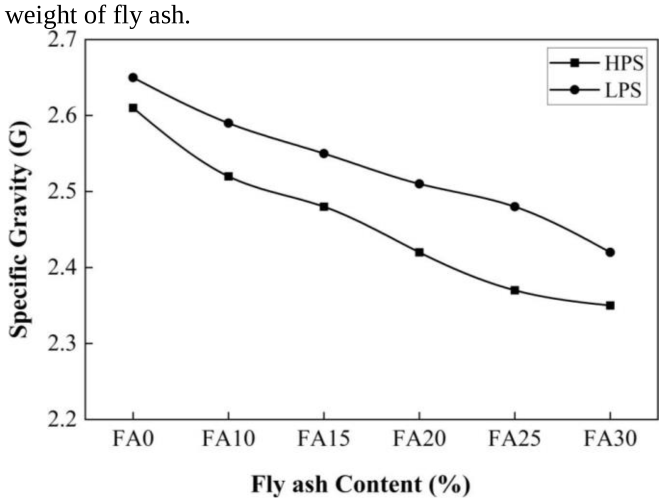

Figure 4. Specific Gravity of fly ash-soil composite

Grain Size Distribution

The grain size distribution curves for HPS and LPS blended with various fly ash content are shown in Figure 5.3. The grain size distribution provides information related to the gradation of the material such as well-graded, poorly graded, uniformly graded, fine, or course. Table 5.1 presents percentage of sand, silt, and clay fraction present in HPS mixed with various proportions of fly ash. Here, expansive soil grain size distribution was altered by the addition of fly ash. It was observed that sand and clay fraction decrease with increase in fly ash content. This was mainly due to the addition of finer particles of non-cohesive fly ash; however, silt fraction increases for all the higher proportion of fly ash mixed with soil. Similar observations were made for LPS. Grain size analysis is a fundamental tool for Quantitative analysis of the percentages of different particulate sizes yields one of the most fundamental physical properties of clastic sediments and sedimentary rocks.

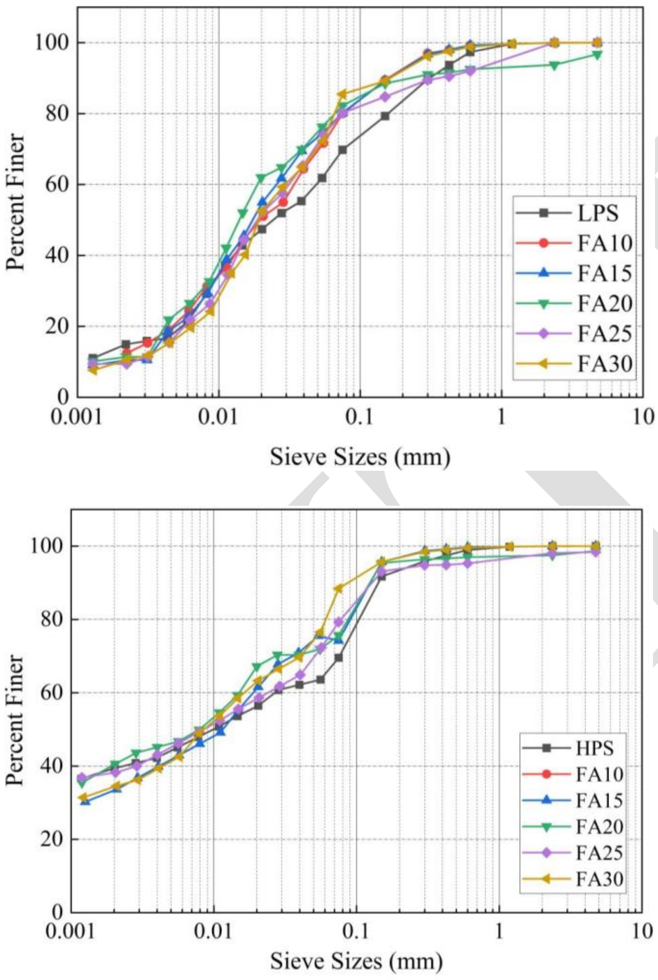

Figure 4 Grain size distribution curve for (a) HPS and (b) LPS

Compaction Characteristics

The standard Proctor compaction and modified Proctor tests were performed to understand the tendency of the density-moisture curve for both soil samples. Figure 5.4 (a and b) shows the variation of MDU and OMC in standard and modified Proctor tests of HPS for various proportions of fly ash. It can be observed that the MDU decreases with increase in fly ash content because of low specific gravity of mixes and absence of any binding properties of the soil with fly ash particles. The MDU increases and OMC decreases with increase in compaction effort for all percentages of soil mix. Figure 5.5 (a and b) shows the variation of MDU and OMC for LPS with fly ash percentage. The OMC of HPS and LPS blended with fly ash was reduced with fly ash increment, because of the reduction of soil clay fraction that reduces the water holding capacity. It was also noted that OMC at higher percentage of fly ash (FA30%) increases; this can be attributed to the progressive hydration of fly ash, which consumes some moisture within the voids .

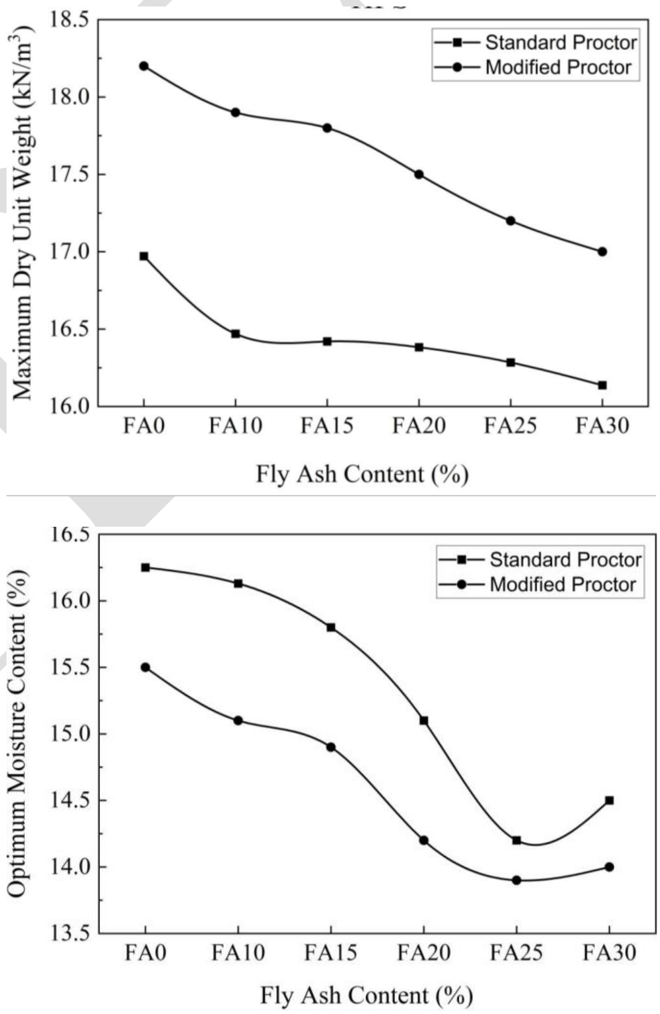

Figure 5 Standard and Modified Proctor Tests for HPS (a) MDU and (b) OMC

Unconfined Compression Strength (UCS)

The UCS test was performed on both soil samples with fly ash mix and for various curing periods of 0 (immediate), 7, 14, and 28 days to understand the behaviour of soil under constant moisture conditions. Figure 5.6 shows the variation of UCS values recorded for HPS for different curing days. The results reveal that with the addition of fly ash, the UCS value decreases rapidly may be because of the breaking of cohesive bonds between soil particles which lose the soil strength. The UCS values get reduced with increase in fly ash content because soil-fly ash mixes do not have any binding properties due to the low amount of lime content (Sridharan et al., 1997). However, UCS values increase with increase in curing periods; because a small amount of calcium forms a cementitious product with respect to time.

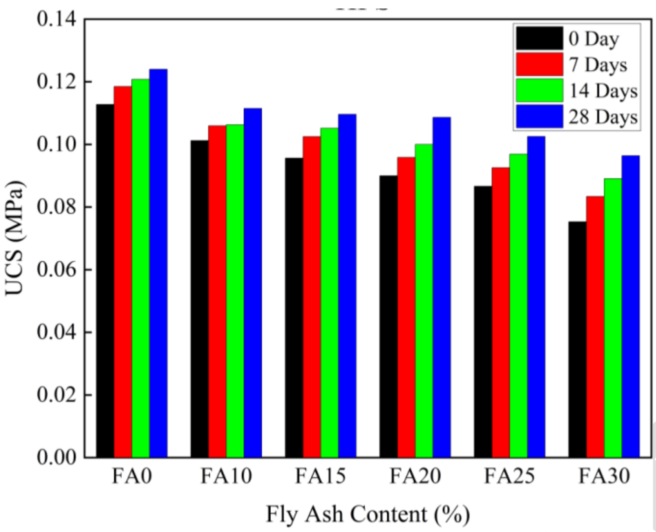

Figure 6 UCS values for HPS

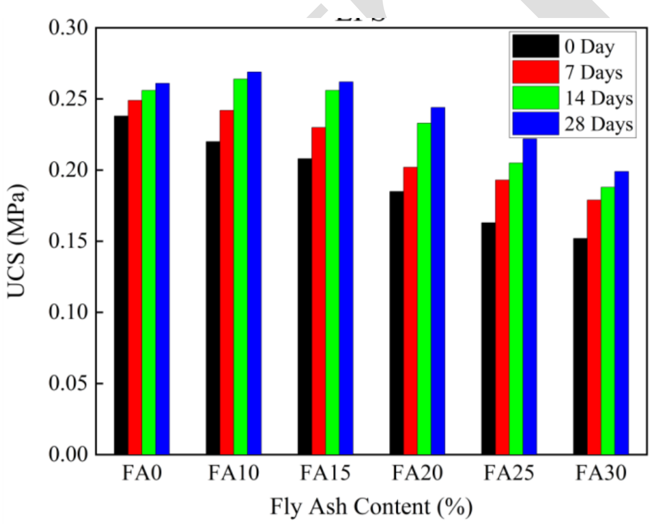

Figure 7 UCS values for LPS

California Bearing Ratio (CBR)

A major application area for fly ash utilization is its use as a subgrade and/or sub-base material in the construction of pavements. For pavement design, the CBR method is used widely. The CBR values of different mixes of fly ash and soil were determined according to IS 2720, Part 16 1987. The specimens were prepared at their respective modified proctor, MDU, and OMC for unsoaked and soaked conditions and respective values were evaluated. From the results shown in Figure 5.9 and Figure 5.9, improvements in both unsoaked and soaked CBR values can be observed with increase in fly ash content. A similar trend of improvement in CBR values was observed by various researchers (Bose, 2012; Pandian, 2004; Petersen et al., 2001; Sridharan et al., 1998). It was mainly due to increase in silt and reduction of clay fractions that can be attributed to the better packing of different soil mixes. Therefore, in conclusion, with the addition of fly ash to the soil, an improvement in the gradation, as well as compacted strength, offers better resistance against penetration.

V. CONCLUSIONS

These following conclusions are given based on the above experimental results. Feasibility of stabilizer has been investigated in terms of index and engineering properties of soil based on experimental investigation, numerical and statistical analysis following conclusions were drawn:

A. Based on Moorum- Fly ash blend

1. Atterberg's limit of moorum fly ash mix changes to non-plastic from plastic state with partial replacement of fly ash content. The specific gravity of the moorum fly ash mix was reduced with increase in fly ash content because of the lightweight of fly ash.

2. As the fly ash content increases in moorum-fly ash mixes, the maximum dry unit weight was reduced, while optimum moisture content increase. The CBR value for the moorum fly ash mix decreases with increase in the percentage of fly ash.

3. The cohesion of moorum-fly ash mixes increases with increase in fly ash content, whereas the angle of internal friction decreases as a result of the cementation and hardening properties of the fly ash.

4. Based on the numerical simulation (FLAC/SLPE) of moorum fly-ash mix, the FoS of the embankment increases with increase in the fly-ash content, whereas FoS decreases with increase in height and slope angle.

5. The non-linear equation was developed based on the statistical tool to show the relationship between dependent (FoS) and independent variables (FA, γ, ϕ, c, β, and H).

The developed mathematical relation gives a reasonably good prediction of FoS as validated with numerical simulation.

6. Adequacy of the developed model was verified with reference to the R^2, Adj R^2, and Pred R^2 and residual plot for the fitted data and normal percentage plot that shows the strong fitting to obtained results.

B. Based on Expansive soil-fly ash blends

1. The Atterberg's limit and specific gravity of the expansive soil-fly ash mix decrease with increase in fly ash contents.

2. The grain size distribution of expansive soil was altered by the addition of fly ash. It was shifted to the coarser side as the silt and sand fractions increased, whereas the clay fraction decreased with increase in amount of fly ash.
3. Maximum dry unit weight (MDU) of expansive soil continuously decreases with increase in fly ash content because of lowering of specific gravity of soil mixes and due to the absence of binding properties of soil with fly ash particles (inert). The MDU of expansive soil increases with increasing compaction efforts. The optimum moisture content also gets reduced with increase in fly ash contents except for FA30%. The LPS has higher MDU compared to HPS.
4. The UCS value of blends decreases rapidly with increase in fly ash content, this may be because of breaking of cohesive bonds between soil particles as a result reduction in strength.
5. UCS value increases with increase in curing days because soil-fly ash mixes form a small amount of cementitious material from calcium present in fly ash with respect to time. The LPS has higher UCS value compared to HPS. Because HPS is more cohesive in nature and clay fractions are subjected to easy deformation under minor loading.
6. CBR value increase in both unsoaked and soaked conditions with increase in fly ash contents. This may be due to increase in sand and silt fractions whereas reduction in clay fractions as a result that attribute better packing of different fractions of soil mixed with fly ash particles.

VI. REFERENCES

1. Bell. F. G., "Stabilization and treatment of clay soils with lime"-Part-1, Basic Principles of Ground Engineering, vol - 21-1,1988, 10-15. [2]

2. Shivapullaiah. P.V. et al, "Effect of fly ash on the index properties of black cotton soil", Soils and Foundations, vol36, 1996, 97-104.

3. [3] Uppal. H.L. et al., "A Resume on the Use of Flyash in Soil Stabilization", Road Research papers, 1965, No.95. [4]

4. Amarjit Singh, "Use of lime-fly ash in soil stabilization for roads", Journal Of Indian Roads Congress, vol-XXX-1, 1967, 143. [5]

5. Amos. D. F. et al, "The effect of soil fly Ash on soil physical characteristics", Proceedings of Third Mineral Waste Utilization Symposium, Chicago, 1972, 95-104. [6]

6. Chen, F. H., "Foundation on expansive soils", Elsevier Scientific Publishing Co., Amsterdam, 1988. [7]

7. Holtz.W.G. et al, "Engineering. Properties of expansive clays", Transactions, ASCE, vol.121, 1956, 53- 87. [8]

8. Seed. H. B. et al, "Prediction of swelling properties of compacted clays", Journal of Geotechnical Engineering Division, Proceedings of ASCE, 88, 1962, 97-104. [9]

9. Dakshanmurthy. V. et al, "A simple method of identifying expansive soil", Soil and Foundations, Japanese Society of Soil Mechanics and Foundation Engg., vol-13(1), 1973, 97-104002E

10. Ogundipe, O.M. (2013), „An Investigation inti the use of Lime4 Stabilized Clay as Subgrade Materials‟, International Journal of Scientific & Technology Research, Vol-2, Issue-10, P-82-86.

11. Oyediran, I.A., Okosum, J. (2013), „An attempt to improve geotechnical properties of some highway lateritic soils with lime‟, RMZ-M&G, Vol-60, P- 287-296.

12. Muhmed, A., Wanatowski, D. (2013), „Effect of Lime Stabilization on the Strength and Microstructure of Clay‟, Journal of Mechanical and Civil Engineering, Vol-6, Issue-3, P-87-94.

13. Rao, Koteswara. D., Rameswara, Rao. G.V.V., Pranav, P.R.T. (2012), „A Laboratory Study on the Affect of Rice Husk Ash and Lime on the properties of Marine Clay‟, International Journal of Engineering and Innovative Technology (IJEIT), Vol 2, Issue-1, P-345-353.

14. Biswas, S., Biswas, A., Dighade, A. (2014), „Utilization of Rice Husk Ash with Lime in Subgrade Soil for a Rural Road‟, Proceedings published in International Journal of Computer Applications (IJCA), P-1-3.

15. Sarkar, G., Islam, R., Alamgir, M., Rokonuzzaman. (2012), „Interpretation of Rice Husk Ash on Geotechnical Properties of Cohesive Soil‟, Global Journal of Researches in Engineering Civil and structural Engineering, Vol-12, Issue-2, P- 1-7.

16. Mishra, N.K., Rath, S., Pradhan, P.K. (2012), „Lime Stabilization of Weak Sub- Grade for Construction of Rural Roads‟, International Journal of Earth Science and Engineering, Vol-5, No-3, P-554-561.

17. Saklecha, P.P., Katpatal, Y.B., Rathore, S.S. (2011), „Spatial Correlation of Mechanical Properties of Subgrade Soil for Foundation Characterization‟, International Journal of Computer Applications, Vol-36, No-11, P-20-24.

18. Mtallib, M.O.A., Bankole, G.M. (2011), „The Improvement of the Index Properties and Compaction Characteristics of Lime Stabilized Tropical Lateritic Clay with Rice Husk Ash Admixture‟, EJGE, Vol-16, P-983-996.

19. Sreedhar, M.V, Kunduru, M. (2011), „Compaction and CBR Characteristics of Lime Stabilized Pond Ash, Proceeding of Indian Geotechnical Conference‟, Kochi, P-697-699.

20. Dutta, T., Chattopadhyay, B.C. (2011), „Correlation between CBR and Index Properties of Soil‟, Proceeding of Indian Geotechnical Conference, Kochi, P- 131-133.

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