International
Journal
Of Advanced Research in Engineering & Management (IJAREM)
ISSN: 2456-2033 || PP. 17-22

Effect of Fly Ash Geopolymer on Geotechnical Properties of Soil

Harishma Raveendran[1], Anjana T. R[2].
(PG student, Dept. of Civil Engg., Thejus Engineering college, India)
** *(Assistant Professor, Dept. of Civil Engg., Thejus Engineering college, India)*

Abstract: Soil stabilization is a term used for improving mechanical, chemical, physical, biological or combined method to improve the properties of natural soil and making it fit for engineered purpose. The main objective of this study is to improve the properties of the soil by adding the waste material which can cause environmental pollution. Fly ash is a waste product from power plants has been selected to add in the soil sample in different ratios (0%, 5%, 10%, 15% and 20%). Liquid alkaline activator is produced by the mixing Na_2SiO_3 solution with NaOH in 3:1 ratio. The soil properties with and without adding of fly ash based geopolymer have been studied. An attempt has been made to use these waste materials for improving the Atterberg limits, compaction characteristics, unconfined compressive strength and CBR values of soil.
Keywords: Atterberg limits, compaction characteristics, CBR value, geopolymer, unconfined compressive strength

1. Introduction

Clay soil presents problems to geotechnical engineers because of its complex nature. The stabilization of the clay by treatment in situ to a remarkable depth is necessary if the often more expensive structural solutions to such problems are to be avoided. Chemical alteration of clay has been shown to be effective in increasing its stiffness and strength and, when combined with long-term cementing reactions, significant improvements can be achieved. Recycling and utilizing of waste material is a significant contribution to environment and sustainable development.

Geopolymers are a group of cementitious materials that has garnered increasing interest as an alternative stabilizing agent to replace portland cement. Specifically, fly ash-based geopolymers were reported to leave essentially no carbon footprint relative to portland cement. The chemical process to produce geopolymers involves the co-polymerization of alumina and silica components whereby aluminosilicate-rich materials are dissolved by highly alkaline solutions such as sodium hydroxide (NaOH). Sodium silicate (Na_2SiO_3) can further increase the strength of the geopolymer because of the gel-like product derived from the aluminosilicate-sodium silicate reaction. Calcium carbide residue (CCR) is a by-product of the acetylene production process that contains mainly calcium hydroxide, $Ca(OH)_2$. CCR is $Ca(OH)_2$-rich materials can be utilized together with waste pozzolanic materials, such as fly ash, biomass ash and rice husk ash to develop a cementitious material. Consequently, this study attempts to study the possibility of using calcium carbide residue and fly ash based geopolymer to develop strength of clay for using as construction and pavement materials.

2. Previous research

Chayakrit Phetchuay et al. [1] examine the viability of using FA and CCR based geopolymer as a sustainable binder to improve strength of soft marine clay. The strength of stabilized soil was found to be strongly dependent upon FA content and NaOH concentration. The optimal ingredient providing the highest strength was found to be dependent on water content.

Zhen Liu et al. [2] study the feasibility of FA based geopolymer on loess stabilization. The metastable structure of natural loess has resulted in construction delays and catastrophic failures. It is found that KOH renders a higher unconfined compressive strength than NaOH geopolymers. With an increasing FA/loess ratio, the compressive strength and Young's modulus increase. The micro structural characterization unveils that a compact and stable microstructure has been developed in the stabilized loess.

Zongjin Li et al. [3] found that the incorporation of slag could significantly increase the compressive strength of the geopolymer. The XRD and FTIR results showed that the addition of slag could generate more amorphous products and accelerate the reaction rate of raw materials. From XPS results, the decrease of binding energy and broadening of peaks were observed due to the Ca^{2+} provided by slag. Besides the chemical effects, the physical effects of slag incorporation on microstructure had been investigated using MIP. The reduced total volume of porosity and refined pore size must have contributed to the strength enhancement for the geopolymer with slag addition.

Chao-Lung Hwang et al. [4] investigated the effect of alkali activator and rice husk ash content on strength development of fly ash and residual rice husk ash based geopolymers. Compressive strength of all the geopolymer samples increased with curing age. Development of compressive strength in the geopolymer samples was dependent on NaOH concentration and RHA content.

3. Materials and methodology

3.1 Materials

3.1.1 Soil

This soil was collected from a site nearby Punkunnam, Thrissur. The collected soil was light brownish in colour. Preliminary testing revealed that the soil was CH classification. Disturbed samples were collected at a depth 2m below the ground. Physical properties of soil are tabulated in TABLE 1.

Table 1: Properties of soil

Sl. No	Properties	Values
1	Initial water content (%)	13.00
2	Specific gravity	2.67
3	Particle size distribution 1) Gravel (%) 2) Sand (%) 3) Silt (%) 4) Clay (%)	 0 40.00 28.00 32.20
4	Liquid Limit (%)	54.00
5	Plastic Limit (%)	25.00
6	Shrinkage Limit (%)	14.00
7	IS classification	CH
8	Maximum Dry Density (kN/m^3)	17.71
9	Optimum moisture content (%)	15.00
10	Unconfined Compressive Strength (kN/m^2)	46.70
11	California Bearing Ratio (%)	1.32
12	Free swell index (%)	25.00

3.1.2 Fly ash

Fly ash (FA) is obtained from one of the coal combustion products. The chemical properties of the fly ash are largely influenced by the chemical content of the coal burned. Fly ash used in this study was obtained from Ernakulum. Fly ash contains 12.15% of CaO, 44.69% of SiO_2, 23.91% of Al_2O_3, 10.52% of Fe_2O_3, 2.34% of MgO, 1.32% of SO_3 and 2.11% of K_2O. It belongs to class C.

3.2 Methodology

The properties of soil selected for this study was determined in the laboratory according to the relevant I.S. code. Liquid alkaline activator is prepared by mixing Na_2SiO_3 solution with NaOH solution in a ratio of 3:1. FA is added to clay soil at 5%, 10%, 15% and 20% to prepare FA geopolymer. Geopolymer is prepared by adding liquid alkaline activator to a mixture of soil and fly ash. And the strength characteristics are evaluated.

Laboratory tests conducted are light compaction test, unconfined compressive strength test and California bearing ratio test.

4. Results and discussions

4.1 Atterberg limits (IS 2720: part V & VI)

4.1.1 Liquid limit

The fig.1 shows the effect of varying percentages of fly ash on the liquid limits of selected soil sample. The liquid limit decreases with increasing the amount of fly ash. This is due to reduction in the specific surface area of the soil. The monovalent cations are replaced by divalent cations leads to decrease in diffused double layer thickness and consequent decrease in the water holding capacity.

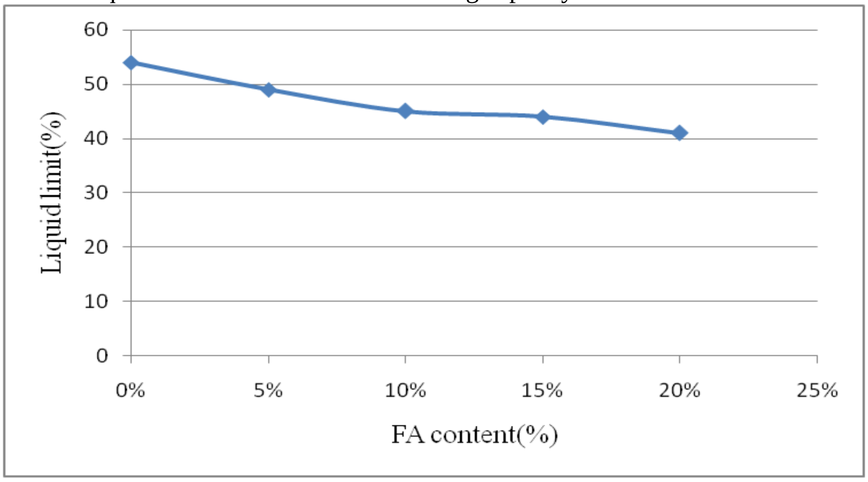

Fig.1: Variation of Liquid limit on FA geopolymer soil

4.1.2 Plastic limit

The fig.2 shows variation of plastic limit with the addition of fly ash. There is a decrease in plastic limit with increase in percentage of fly ash. This is due to decrease in diffused double layer thickness of clay particles leads to increase in shearing resistance. The soil fabric varies with changes in exchangeable cation and concentration of fly ash. Plastic limit of soil is also depends on the particles arrangement, size and shape of the pores.

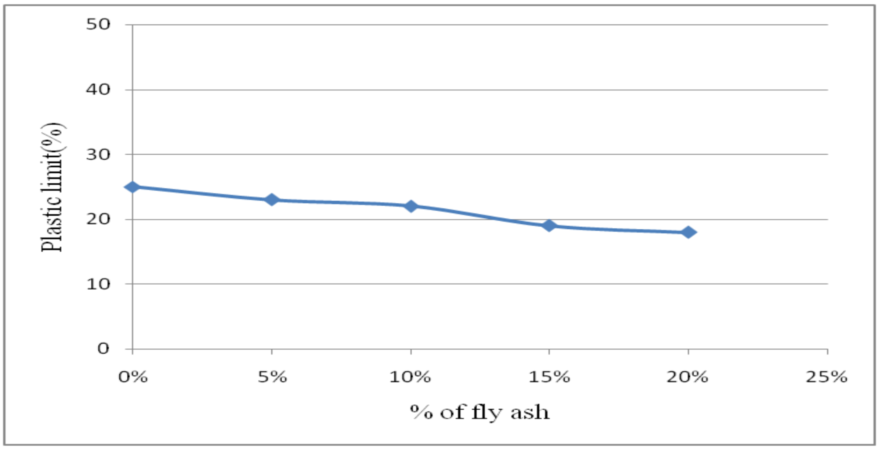

Fig.2: Variation of Plastic limit on FA geopolymer soil

4.1.3 Shrinkage limit

The fig.3 shows variation of shrinkage limit with the addition of fly ash. There is a decrease in shrinkage limit with increase in percentage of fly ash. The addition of non-shrinking and cohesion less fly ashes in soil decrease the tendency of soil geopolymer mixture to shrink.

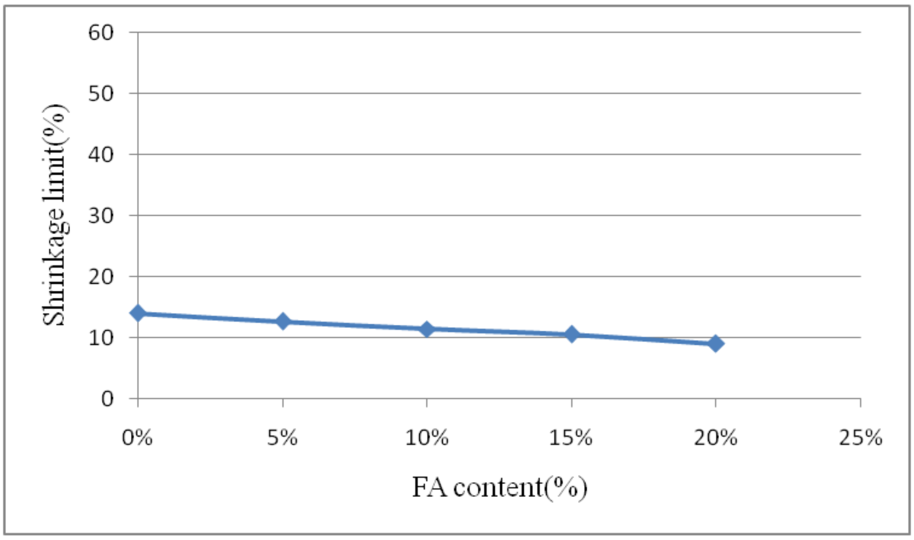

Fig.3: Variation of Shrinkage limit on FA geopolymer soil

4.2 Standard proctor test (IS 2720: part – VII, 1979)

Standard proctor tests were conducted on 5%, 10%, 15 %, and 20 % of fly ash was mixed to the soil. The optimum moisture content and maximum dry density have an important role in changing the strength properties of clay. The result obtained for optimum moisture content and maximum dry density for FA geopolymer is shown in fig.4 to fig.5.

The inclusion of low weight and coarser fly ashes in soil can make the mixed samples comparatively coarser and decrease the overall weight. The decrease is resulted from the flocculation and agglomeration of clay particles in presence of sufficient water leading to increase in voids and corresponding decrease in dry densities. The reason for increasing optimum moisture content may be attributed to the affinity of the soil- fly ash mixed sample for more water to complete the cation exchange reaction and with application of compaction effort the voids are occupied by more water.

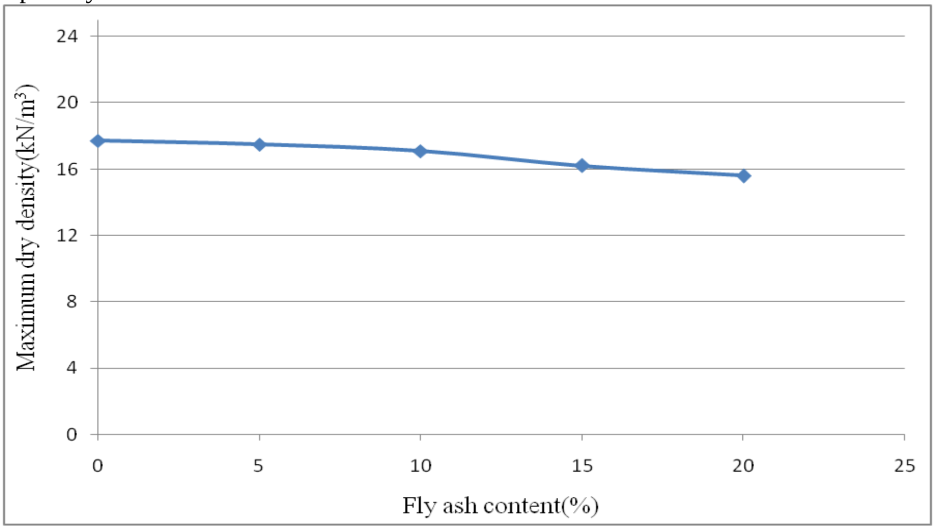

Fig.4: Variation of MDD on FA geopolymer soil

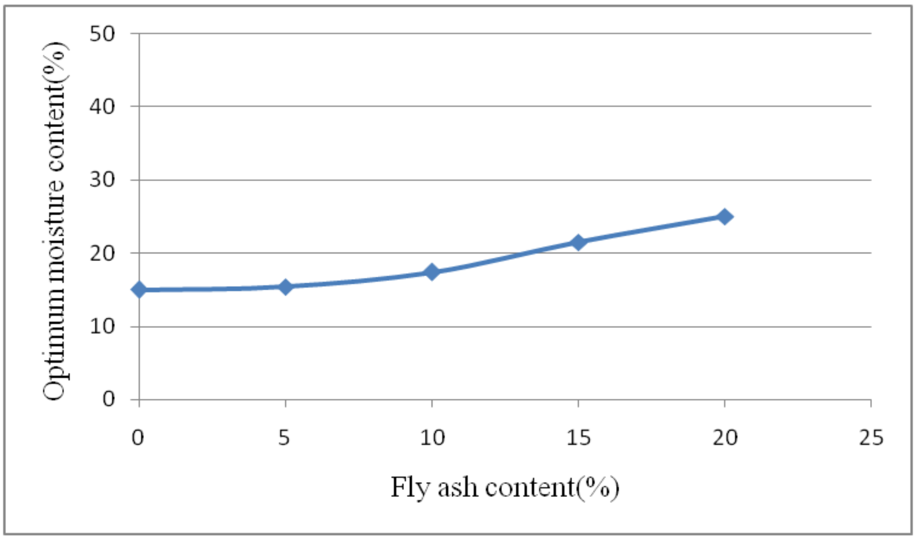

Fig.5: Variation of OMC on FA geopolymer soil

4.3 Unconfined Compressive Strength of Soil (IS 2720: Part X, 1991)

The results obtained are shown in fig.6 for fly ash geopolymer. Unconfined compressive strength values increased with increased percentage of fly ash upto optimum vale and then show a decreasing trend with the addition of fly ash. Maximum strength is obtained at 15% of fly ash. The increase in unconfined compressive strength value is due to the formation of calcium silicate hydrate and calcium aluminate hydrate during geopolymerization. Fly ash is rich in silicate and aluminate and can form cementitious material when react with silicate solution and hydroxide solution.

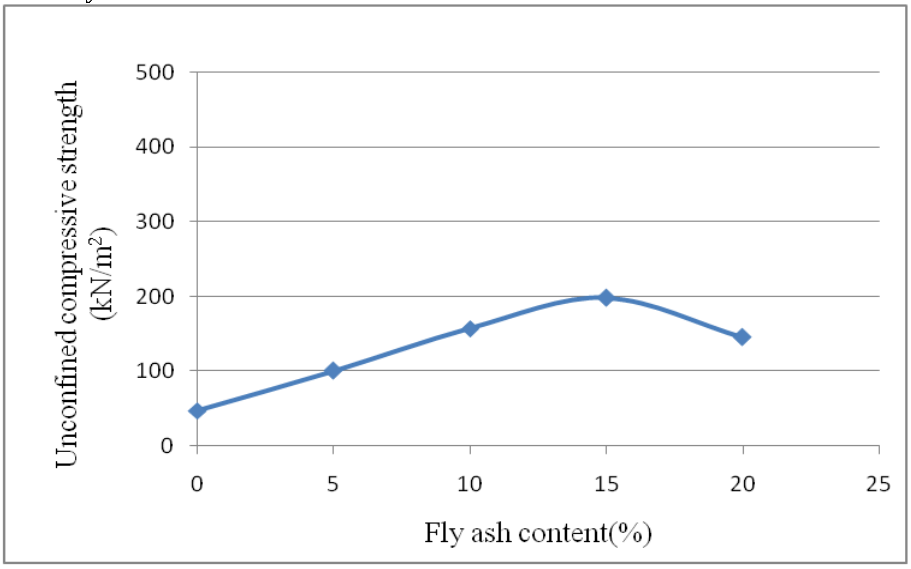

Fig.6: Variation of UCS on FA geopolymer soil

4.4 California Bearing Ratio test (IS 2720: part-XVI, 1987)

California bearing ratio tests were conducted on 5 %, 10%, 15 % and 20 % of fly ash was mixed to the soil. The CBR value increases upto the optimum level due to the frictional resistance from the fly ash in addition to the cohesion from soil. After the optimum level CBR value decreases with the addition of fly ash. The decrease in CBR value is due to the pore water filled in the flocks. It was found that 15% is optimum percentage of fly ash for maximum strength of soil. The variations in CBR values are shown in fig.7.

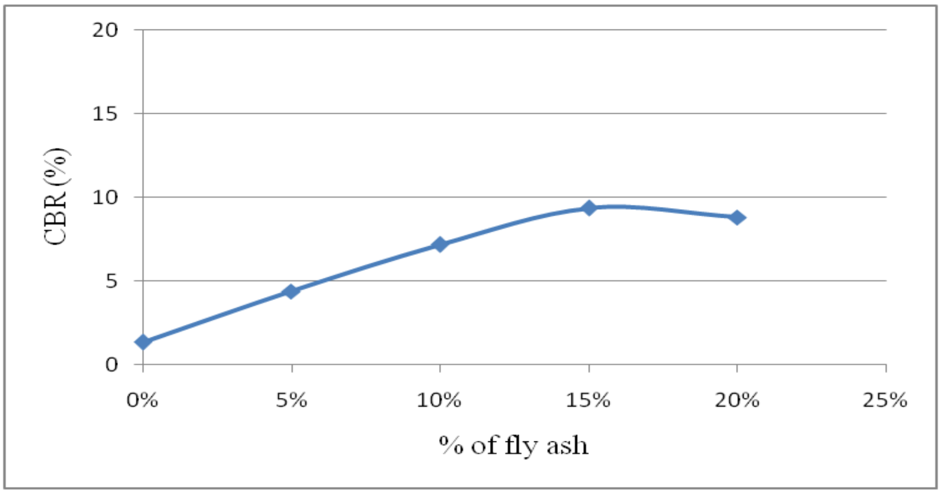

Fig.7: Variation of CBR on FA geopolymer soil

5. Conclusions

In this study, the feasibility of using fly ash geopolymer as a soil stabilizer was confirmed. Geopolymer has the ability to form a dense structure and hence even the soils with low reactivity and undesirable structure were also strengthened. It can be concluded that the addition of fly ash geopolymer has improved the following soil properties considerably:

- Liquid limit decreased by 32% with increased amount of fly ash
- Plasticity index decreased by 7% with increased amount of fly ash
- Maximum dry density decreased by 12% whereas the OMC increased by 67% with the addition of fly ash
- CBR values and UCS values increased by 600% and 320% with the addition of fly ash upto optimum value and then decreased

References

[1]. C. Phetchuay, Suksun Horpibulsuk, Arul Arulrajah, Cherdsak Suksiripattanapong and Artit Udomchai, Strength development in soft marine clay stabilized by fly ash and calcium carbide residue based geopolymer, *Applied Clay Science, ELSEVIER, 2016, 134-142*

[2]. Zhen Liu, C. S. Cai, Fengyin Liu and Fenghong, Feasibility study of loess stabilization with fly ash–based geopolymer, *Journal of Materials in Civil Engineering, ASCE, 2016*

[3]. Zongjin Li and Sifeng Liu, Influence of slag as additive on compressive strength of fly ash-based geopolymer, *Journal of Materials in Civil Engineering, ASCE, 2007,* 470-474

[4]. Chao-Lung Hwang and Trong-Phuoc Huynh, Effect of alkali-activator and rice husk ash content on strength development of fly ash and residual rice husk ash-based geopolymers, *Construction and Building Materials, ELSEVIER, 2015,* 1-9