Physical and Strength Characteristics of Fly Ash Stabilized Soft Soil

Saddy Ahmed[1], Aqsa Jamil[2], Waseem Yasin[3]

1. Lecturer, Department of Civil Engineering, National University of Computer and Emerging Sciences, Lahore, Pakistan
   Email: (ahmedsaddy.nu@gmail.com)
2. Department of Technology, The University of Lahore, Pakistan,
   Email: (aqsaddy@gmail.com)
3. Department of Technology, The University of Lahore, Pakistan,
   Email:(waseemm066@gmail.com)

ABSTRACT

The engineering properties of soft soils can be improved by mixing with suitable agents and one of them is fly ash. The sole object of this research is to check the effect of varying dosage of fly ash class C on physical and strength characteristics of soft soil. To check the result of fly ash contents on soil properties, a varying dosage from 0-10% was mixed with virgin soil. Soil mineral identification, specific gravity, consistency limits, compaction characteristics, California bearing ratio (CBR) and unconfined compressive strength (UCS) tests were performed on treated as well as untreated samples according to the related ASTM procedures. In addition, UCS tests were performed over an extended period of 0, 3, 7, 14 and 28 days to check the impact of curing period on strength development. The test results showed that California bearing ratio (CBR) and unconfined compressive strength (UCS) increased while plasticity reduced with the increment in fly ash contents.

Keywords: California bearing ratio, fly ash, plasticity, soft soils, unconfined compressive strength

1. INTRODUCTION

In many regions of the world, the common civil engineering problem is the construction of roads and railway over soft soils as such soils exhibit high compressibility and low strength. Subgrade soil with California bearing ratio (CBR) less than 8 are considered as soft soils and not suitable for road construction (Ozdemir, 2016). The common practice to build a railway or highway on soft soils is to replace them with good quality borrow materials. The uneconomical nature of this cut and fill technique forces engineers to upgrade the engineering properties of soft soils using different additives. For the enhancement of physical and engineering properties, one way to strengthen these weak soils is to compact them at their maximum dry density to reduce the pores. Secondly, different treatments can be used in earth-structures to achieve the required properties of geomaterials such as shear strength and compressibility, etc. Soil improvement using various waste products has a double advantage, i.e., the weak ground is stabilized, and hazardous waste from industries is recycled (Show, Tay, Goh, & Ash, 2003). Moreover, the dumping of weak soil and hazardous industrial waste is not required (Sridharan, 2013). There are different types of stabilizers which can be employed to modify the engineering characteristics of geomaterials. The choice of stabilizer based on the nature of chemical reaction with the soil and water. Most commonly used stabilizers include lime, cement, fly ash, and marble dust (Mahvash, López-querol, & Bahadori-jahromi, 2017). Result of mixing fly ash on Atterberg's limits of soft clay was examined by (Jafer, Atherton, Sadique, Ruddock, & Lo, 2018) and concluded that adding fly ash to soft soil causes an increase in liquid limit while the reduction in plasticity index. (Edil et al., 2006) checked the impact of fly ash contents on CBR values of fine-grained soil and concluded that adding 10% fly ash increased the CBR values from 8% to 17%. (Chang, Lund, Page, & Warneke, 1977) studied the physical characteristics of fly ash modified soils and concluded that bulk density reduced with the intensification in fly ash contents. When mixed in the soil, fly ash help to start the process of flocculation of the fine grain particles. Further, it leads to the pozzolanic reactions and cation exchange for the formation of cementitious compounds that improve mechanical characteristics of soil (Prabakar, Dendorkar, & Morchhale, 2004). This process results in the improvement of mechanical performance and workability of soil after compaction (Brooks, 2009). The properties of fly ash treatment have numerous technical guides available in many countries around the world. These guides and recommendations made by various researchers encourage us to back the utilization of this waste product for soil stabilization. The current study aims to assess the outcome of fly ash stabilization on Atterberg's limits, compaction and strength characteristics of soft soil present in Pakistan. Fly ash is a hazardous waste product resulting from coal power plants available easily in Pakistan and cheaper than cement and lime. It is better to utilize fly ash in soil improvement instead of dumping in a fertile land which may pollute the ecosystem.

2. EXPERIMENTAL PROGRAM

The sample of soft soil discussed in this research was retrieved from a roadway site located near district Sheikhupura, Pakistan. An undisturbed soil sample along with a disturbed sample was collected for laboratory testing. Both samples were retrieved after digging a pit to an average depth of 2ft below the ground surface. To keep the in situ moisture contact the undisturbed block sample was sealed with wax while disturbed soil sample was preserved in airtight plastic bags. In-place density and field moisture content were measured from the undisturbed soil sample while the disturbed sample was used for further testing. Various percentages of fly ash, ranging from 0-10% were mixed with the collected soil sample with increments of 2% as specified by most of the researchers. Table 1 illustrates the measured physical characteristics of virgin soil sample used in this research. The list of tests performed on fly ash, virgin soil and amalgamated soil samples is as follows:

a) Water Content Determination (ASTM D-4643)
b) Mineralogical Composition by Petrographic Test (ASTM C-295)
c) Gradation Analysis (ASTM D-422)
d) Atterberg's Limits Test (ASTM D-4318)
e) Modified Proctor Compaction Test (ASTM D-1557)
f) California Bearing Ratio (ASTM D-1887)
g) Unconfined Compression Test (ASTM D-2166)

Table 1: Physical characteristics of virgin soil sample

Test	Properties	Result
Sieve Analysis	Gravel (%)	1.9
	Sand (%)	32.2
	Silt & Clay (%)	65.9
Atterberg's Limits	Liquid Limit (%)	31.6
	Plastic Limit (%)	18.2
	Plasticity Index (%)	13.4
Specific Gravity	G_s	2.76
Compaction Test	Optimum Moisture Content (%)	9.2
	Max Dry Density (kN/m^3)	19.3
Strength Tests	Unconfined Compressive Strength (kPa)	317
	California Bearing Ratio (%)	3.0
Soil Classification	USCS group symbol	CL

Following overall observations can be drawn based on the tests conducted on the parent soil as well as stabilized soil samples:

- The field water content of the soil sample was calculated based on the average of six samples taken from block sample according to ASTM procedures mentioned in (ASTM, 2014) which resulted to be 7%.
- Determination of in-place density was carried out by taking an average of four core cuter samples taken from block sample which came out to be 17.9 kN/m^3.
- The sieve analysis conducted on soil sample depicts that it has a high percentage of fine particles. The gradation results of both soil sample and fly ash are presented in Figure 1.

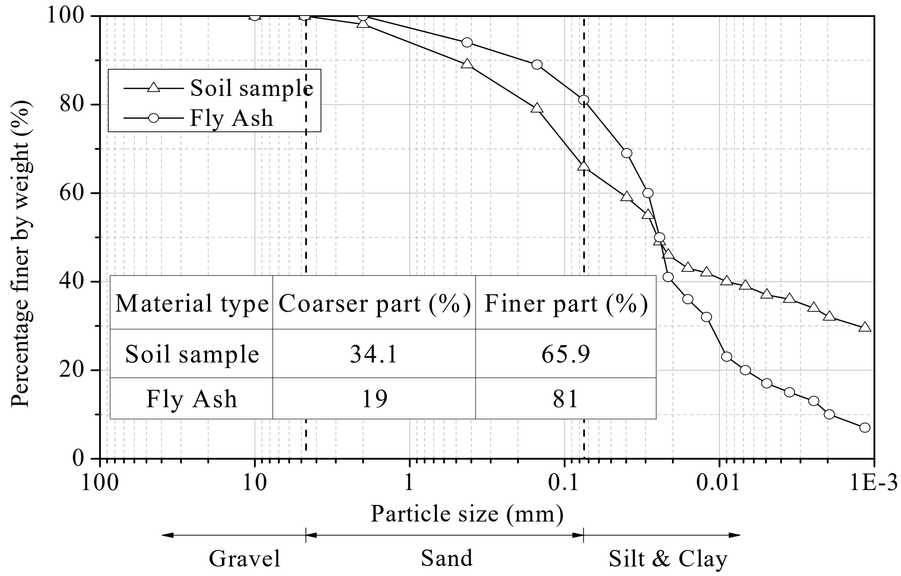

Figure 1. The particle size distribution of soil sample and fly ash

- The mineralogical composition of soil sample and fly ash was determined by petrographic analysis for mineralogical composition following the procedure mentioned in (ASTM C-295). Comprehensive results of the mineralogical composition measured by petrographic analysis are presented in Figure 2.
- Consistency limit state tests were performed on the material finer than sieve # 40 (ASTM International, 2010) and the results indicated that virgin soil sample has a liquid limit (LL) and plastic index (PI) of 31.6% and 13.4% respectively. The same practice was continued for blended samples by mixing fly ash to the soils at the rate of 2% by weight.
- Specific gravity was measured according to ASTM D-854 and based on the average of three trials; it was found that virgin soil has specific gravity 2.76.
- Modified Proctor compaction test was performed according to the guidelines mentioned in (ASTM, 2009) with the help of mechanical mixer and the modified dry unit weight ($\gamma_{d\ max}$) of soil was 19.3 kN/m^3 with optimum moisture content 9.2%.
- Soaked CBR test was performed on virgin as well as fly ash-soil mixes. After compaction of soil mixture, 10 lbs surcharge plates were placed on them. After soaking for 96 hours the prepared samples were tested at 1.3 mm/min penetration rate.
- Cylindrical samples with height/diameter ratio as two (height 76.2 mm and diameter 38.1mm) were tested for unconfined compressive strength (UCS) test in a strain-controlled machine and the final value of UCS was reported based on the average of two samples.

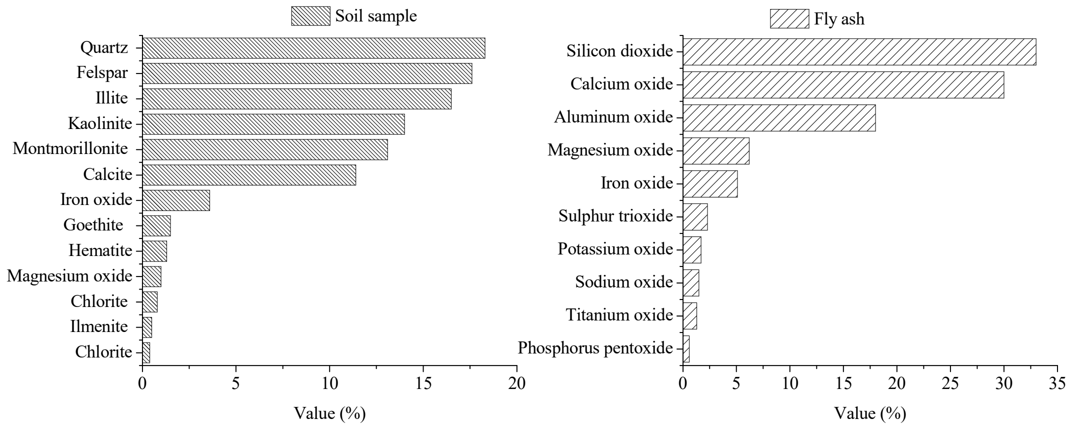

Figure 2. Petrographic Analysis of soil sample and fly ash

3. TEST RESULTS AND DISCUSSION

Detailed outcomes of the tests conducted during this research work on amalgamated soil samples and the result of fly ash on various physical and strength characteristics of the soft soil sample are deliberated below.

3.1 Atterberg's Limits Tests

The outcomes of the consistency limit state tests conducted on the stabilized samples by using fly ash are expressed in Figure 3. From the graph, it is evident that addition of 10% fly ash increased the liquid limit from 31.6% to 35% while the addition of the same amount of additive reduced the plasticity index from 13.4% to 10%.

3.2 Compaction Test

To examine the result of fly ash contents on compaction characteristics ($\gamma_{d\,max}$ and OMC) of the soft soil sample, modified Proctor test was conducted on all treated soil samples and the results are shown in Figure 4. From the graphs, there is a slight decrease in $\gamma_{d\,max}$ by mixing fly ash with the soil while the OMC goes on increasing with the increase of admixture contents.

3.3 California Bearing Ratio (CBR) Tests

Soaked CBR tests were conducted on soil-fly ash composite samples and the results are shown in Figure 5. With the addition of 10% fly ash, CBR value increased from 3% to 8.6% which is well ahead of the threshold value for subgrade material according to the National Highway Authority (NHA) of Pakistan.

3.4 Unconfined Compressive Strength (UCS) Tests

To examine the effect of fly ash contents and curing period on the UCS of the soft soil the samples were made by mixing soil with various fractions of admixture and properly cured to check the mode of strength development. From the test results given in Figure 5, due to the pozzolanic reaction occurring in soil-fly ash mixture, by adding 10 % fly ash to the soil, UCS strength value after 28 days of curing, increased from 317 kPa to 1205 kPa.

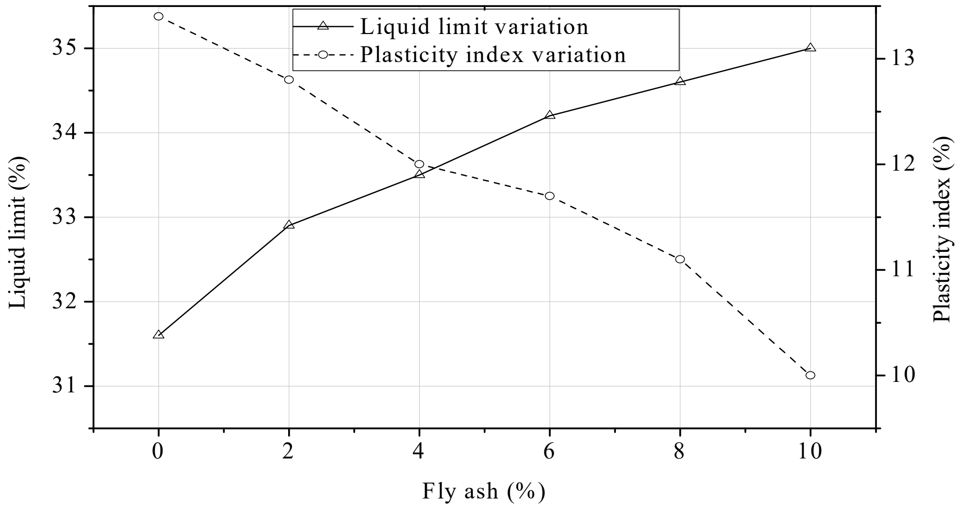

Figure 3. Effect of fly ash on consistency limits of soft soil

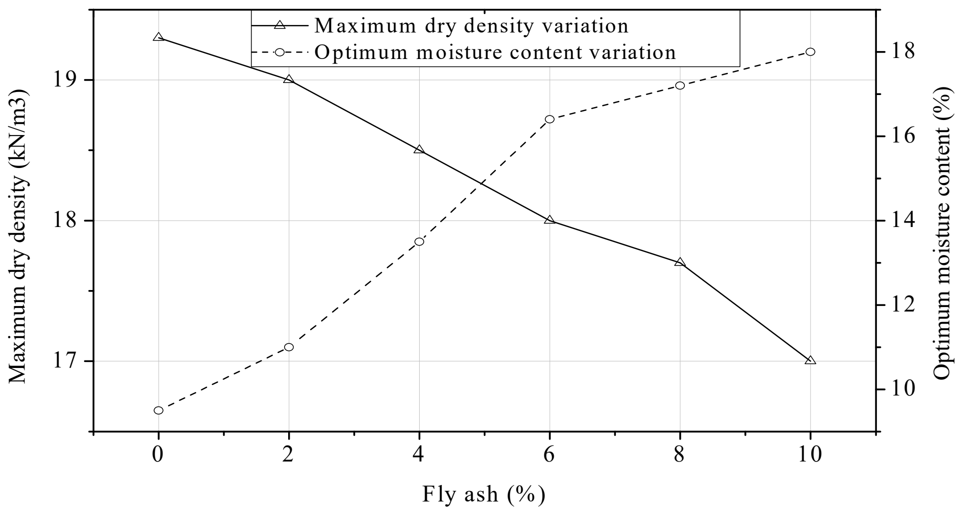

Figure 4. Effect of fly ash on compaction characteristics of soft soil

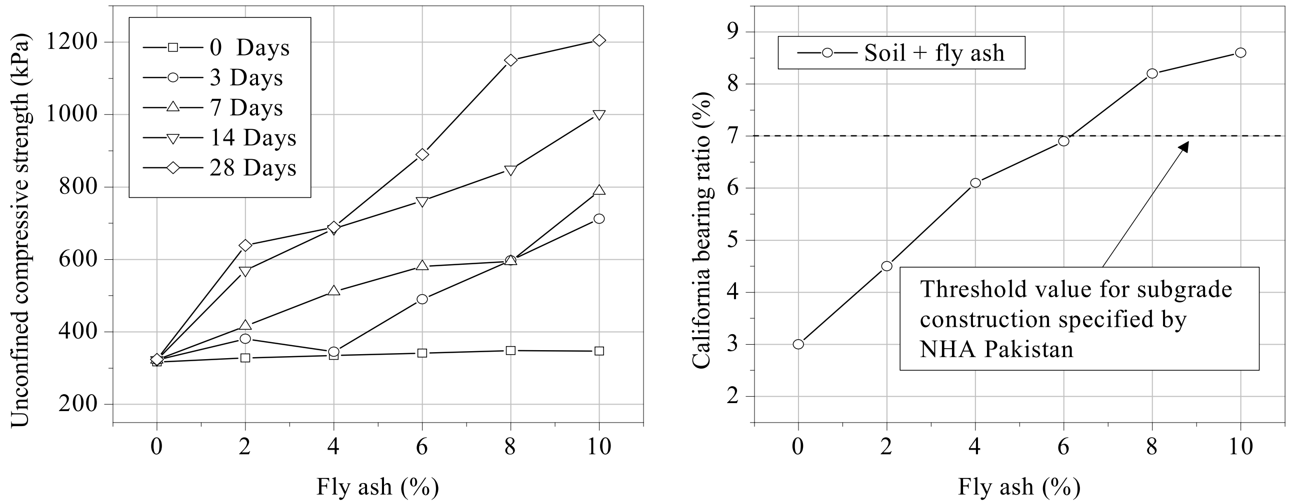

Figure 5. Effect of fly ash on unconfined compressive strength and California bearing ratio of soft soil

4. CONCLUSIONS

From the above study the following conclusions have been made:

- Adding fly ash to the virgin soil reduced the plasticity of the soil.
- The $\gamma_{d\ max}$ of soil slightly reduced with the addition of fly ash contents.
- Mixing of 10% fly ash to soil increased the UCS by almost four folds.
- It is imagined that soil-fly ash mixtures have a mechanism of strength expansion which consists of an immediate exchange reaction of cations and a long term pozzolanic reaction.
- Due to high values of CBR and UCS, it is very beneficial to use of soil-fly ash mixture as a subgrade material to reduce the deformations in these layers.
- However, using this waste product as a soil stabilizer may alter the other properties of soil. Further, it may need an appropriate method to mix the admixture with soil to achieve the desired results. It is better to initiate the use of fly ash from small scale projects.

REFERENCES

ASTM. (2009). Standard test methods for laboratory compaction characteristics of soil using modified effort.

ASTM. (2014). Standard Test Method for Determination of Water (Moisture) Content of Soil.

ASTM (2010).Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.

Brooks, R. M. (2009). SOIL STABILIZATION WITH FLYASH AND RICE HUSK, 1(3).

Chang, A. C., Lund, L. J., Page, A. L., & Warneke, E. (1977). Physical Properties of Fly Ash-Amended Soils 1, 6(3), 267–270.

Edil, T. B., Asce, M., Acosta, H. A., Asce, M., Benson, C. H., & Asce, M. (2006). Stabilizing Soft Fine-Grained Soils with Fly Ash, (April), 283–294.

Jafer, H., Atherton, W., Sadique, M., Ruddock, F., & Lo, E. (2018). Applied Clay Science Stabilisation of soft soil using a binary blending of high calcium fly ash and palm oil fuel ash, 152(April 2017), 323–332.

Mahvash, S., López-querol, S., & Bahadori-jahromi, A. (2017). Effect of class F fly ash on fine sand compaction through soil stabilization. Helicon, (February), e00274.

Ozdemir, M. A. (2016). Improvement in Bearing Capacity of a Soft Soil by Addition of Fly Ash. Procedia Engineering, 143(Ictg), 498–505.

Prabakar, J., Dendorkar, N., & Morchhale, R. K. (2004). Influence of fly ash on strength behavior of typical soils, 18, 263–267.

Show, K., Tay, J., Goh, A. T. C., & Ash, F. (2003). Reuse of Incinerator Fly Ash in Soft Soil Stabilization, (August), 335–343.

Sridharan, B. A. M. A. (2013). Physical and Compaction Behaviour of Clay Soil – Fly Ash Mixtures, 1059–1072.