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Stabilization of Kalimati Soil Using Fly Ash

Shrawan Kumar Yadav [a], Indra Prasad Acharya [b]

[a, b] *Department of Civil Engineering, Pulchowk Campus, Institute of Engineering, Tribhuvan University, Nepal*
Corresponding Email: [a] dudbc.shrawan@gmail.com, [b] indrapd@ioe.edu.np

Abstract

In this paper, Fly Ash which is obtained after burning coal in thermal power plants, is used as a stabilizing agent to stabilize the expansive, compressible and low bearing capacity Kalimati Soil that causes possibility of failure of structures lying over them. The present paper evaluated the influence of Fly Ash on the index and engineering properties of soil by addition of 10%, 20%.30%.40% and 50% of Fly Ash as per weight of the total soil sample. The significant variation in Liquid Limit, Plasticity Index and Swelling Index has been found. In Kalimati Soil, the Liquid Limit decreased 1.03 times, Shrinkage Limit decreased 1.46 times and Differential Free Swell Index decreased 1.14 times. The compaction test results showed increase in Maximum Dry Density (MDD) from 1012.5 kg/m^3 to 1162.5 kg/m^3. The Unconfined Compression Strength (UCS) test showed that its value increased from 229.418 Kpa to 285.64 Kpa .XRD results showed that there is reduction in the amount of clay minerals with the addition of Fly Ash.So With the analysis of the results it is found that the Fly Ash has a good potential to be used as an additive for improving the engineering properties of expansive Kalimati Soil.

Keywords

Fly Ash – Kalimati Soil – Atterberg's Limit – Optmum Fly Ash Content

1. Introduction

Kalimati Soil which is similar to Black Cotton Soil or expansive soil which are also called as Swell Shrink soil have the tendency to shrink and swell with variation in moisture content.As expansive soil constitute the most vulnerable natural hazard to light weight structures the stabilization of this problematic soils by economical means is a burning issue. Fly Ash which is an industrial waste obtained from thermal power plants is one of environmental risk associated with electricity production from fossil fuels combustion with costly landfill deposits and environmental health hazards. [1] About 235 million tons of Fly Ash was produced in India alone in year 2016-17 and is projected to exceed 1000 million ton by 2031-32. [2] Fly Ash is siliceous or alumino-siliceous material which possesses cementitious value in finely divided from and in presence of moisture .react chemically with calcium hydroxide at ordinary temperature to form compound possessing cementing properties [3].Thus the main objective of this paper is to upgrade problematic Kalimati Soil as a construction material using Fly Ash which a waste material.

2. Research Objectives

There is an urgent need to address the soil possible failure in roads and other structure by substituting traditional costly stabilizers with readily available ,cost effective and easy to use Fly Ash with otherwise is just an industrial waste. Following are the objectives set to meet the needs:

1. To find the optimum value of Fly Ash content for sub grade soil stabilization
2. To evaluate the swelling and shrinkage properties of expansive soil and its reduction by the use of Fly Ash
3. To analyze the effect on the compaction characteristics of stabilized soil by the addition of Fly Ash
4. To investigate the effect on the compressive strength of stabilized soil by the addition of Fly Ash in soil at different proportion

3. Literature Review

Soil stabilization refers to the procedure in which a special soil,a cementing material,or other chemical or non-chemical materials are added to a natural soil or a technique use on a natural soil to improve one or more of its properties. Fly Ash contains siliceous and aluminous materials thus can produce an assortment of divalent and trivalent cation Ca^{+2},Fe^{+3},Al^{+2} etc. under conditions that are ionized in nature, which in return can encourage flocculation of dispersed clay particles.As a result ,the surface area of the soil decreases which implies a reduction in the swell potential. Expansive soils can thus be theoretically stabilized in an effective manner by cationic exchange with Fly Ash. Generally the factors for swelling of the Kalimati Soils are as follows:

1. Location of Soil Sample from the ground surface
2. Thickness as well as shape of the sample
3. Change in volume and Nature of pore fluid
4. time and Temperature
5. Stress history and Unit Weight of the taken, etc.

Cokca (2001) found out that swelling pressure decreased by 75% after 7 day curing, and 79% after 28 day curing when soil specimens were treated with 25% Class C Fly Ash (18.98% of CaO).[4].Pandian et al. (2001) made an effort towards stabilization of expansive soil by using Class F Fly Ash. He found that Fly Ash can make for an effective additive when he saw that with 20% Fly Ash content, the CBR value of Black Cotton Soil improved (about 200%) significantly [5]. Phani Kumar et al. (2004) saw that the hydraulic conductivity, swelling properties and plasticity of expansive soil-Fly Ash mixture decreased, whereas the strength and dry unit weight increased with the increase of Fly Ash content in the mix. For a given water content, the resistance to penetration also increased with the increase in Fly Ash content. [6]. Sharma et al. (2007) contemplated the impact on swelling of highly plastic expansive clay, and the compressibility of another non-expansive but highly plastic clay when Fly Ash was employed. At a given dry unit weight of the mixture, the swelling pressure and swell potential showed a decrease by nearly 50%. A decrease by 40% at 20% Fly Ash content in coefficient of secondary consolidation and compression index of both the samples was observed.[7] Buhler et al. (2007) considered the usage of lime and Class C Fly Ash in stabilization of expansive soils. He observed better results with lime than with Class C Fly Ash, when the reduction in linear shrinkage was better when the former was employed. This, however, established the characteristics of Fly Ash as a stabilizing material.[8]

4. Material and Methodology

4.1 Materilas

1. Soil
   The soil was collected from Kalimati site during subgrade construction and brought to the Central Material Testing Laboratory at Pulchowk Engineering Campus.The Soil was oven dried ,pulverized by rubber hammer into small crumbs and passing through 2.36 mm and seived.

Table 1: Geotechnical Properties of Kalimati Soil

Parameters	Code Referred	Value
Sp. Gravity	IS 2720 (part3)-1980	2.46
MDD	IS 2720 (part 7)-1980	1012.5 Kg/m3
OMC	IS 2720 (part 7)-1980	21.75%
NMC	IS 2720 (part 2)-1973	11.26%
FSI	IS 2720 (part 40)-1977	75%
LL	IS 2720 (part 5)-1985	74.06%
PL	IS 2720 (part 5)-1985	50.62%
SL	IS 2720 (part6)-1972	16.72%

2. Fly Ash
   Fly Ash is non-plastic silt spherical in shape which makes a suitable concoction.Both amorphous and crystalline nature of minerals is the content of Fly Ash generated. Its content varies with the change in nature of the coal used for the burning process, but it basically is non-plastic silt. For the purpose of investigations in this study, Fly Ash was obtained from Janaki Fly Ash Industries, Janakpur.Fly Ash has silaca, alumina,ferrous oxide and Calcium Oxide as major chemical component.

4.2 Methodoloy

To evaluate the effect of Fly Ash as a stabilizing additive in expansive soils, series of tests, where the content of Fly Ash in the expansive soil was varied in values of 10% to 50% (multiples of 10) by weight of the total quantity taken. The Indian Standard codes were followed during the conduction of the following experiments:.Further the methodology adopted and the organization of the research is shown in flow chart form in Figure 1

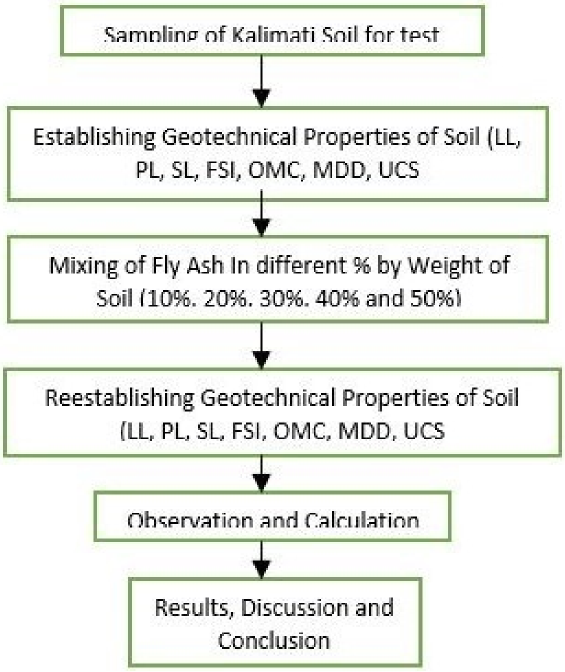

Figure 1: Flow chart showing the methodology adopted for Soil Stabilization Using Fly Ash

To meet the objectives, Parameters are selected keeping in mind that they address the current problems of the expansive Kalimati Soil.Each tests were carried out in the Lab and the results were monitored.Table 1 shows the important parameters considered in the article.

5. Results and Discussions

Atterberg's limits,Differential Free Swell Test ,Standard Proctor Test and Unconfined Compression Strength Test were conducted with different percentages of Fly Ash as an admixtures in kalimati Soil for finding the optimum percentage of additives.

5.1 Liquid Limit and Plastic Limit

From Figure 2 , it is observed that as the percentage of Fly Ash increases ,there is marked reduction in Liquid Limit and Plastic Limit of soil tested.The Liquid Limit of the soil first decreases and again increases after 30% addition of Fly Ash which is due to the effect of reduction in the diffused double layer thickness as well as effect of dilution.This reduced plasticity of Kalimati soil is very much required to avoid the failure patterns over the expansive kalimati soil.

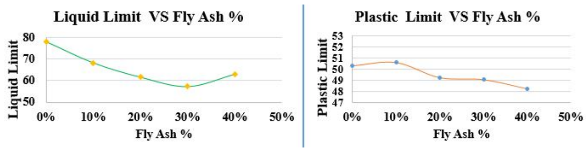

Figure 2: Variation of Liquid Limit and Plastic Limit Of Kalimati Soil Blended with different Fly Ash percentages

5.2 Shrinkage Limit and Free Swell Index

Figure 3 present the variation of Shrinkage Limit and FSI with the addition of Fly Ash showing decreasing value with the increase in Fly Ash.As the Fly Ash is added because it contains some calcium ions that reduce the surface charge of clay particles and and Fly Ash acts as a mechanical stabilizer by replacing some of the volume held by clay particles and fly ash cements the soil particles together and hence reduced sawelling and shrinkage of the treated soil is observed. [9], [4].

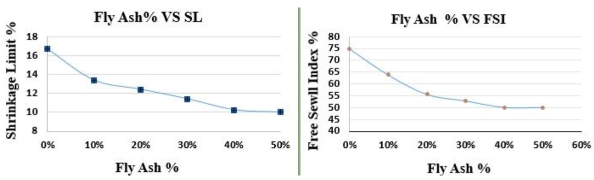

Figure 3: Variation of Liquid Limit and Plastic Limit of Kalimati Soil blended with different Fly Ash percentages

5.3 OMC and MDD

Figure 4 shows the variation of the Optimum Moisture Content(OMC) and Maximum Dry Density(MDD) of Kalimati Soil with Fly Ash content .It depicts that the Optimum moisture content of the kalimati soil has increased from 21.75% to 37.25% with 30% with decrease in OMC with further addition of Fly Ash.The increment of OMC was probably produced by the coarse grain size of Fly Ash compared to that of natural soil , which caused an enlarged void ratio in soil mixtures.The MDD has increased from 101.25 kg/m3 to 116.25 kg/m3 for 30% Fly Ash with further decrease in MDD with addition of Fly Ash.

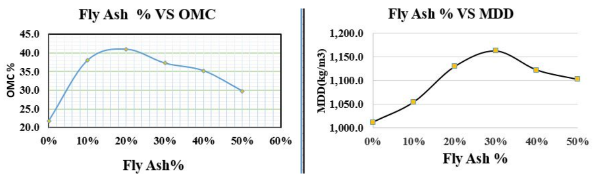

Figure 4: Variation of different parameters Of Kalimati Soil blended with different Fly Ash percentages

5.4 Unconfined Compressive Strenth (UCS)

The variation of UCS for all the samples are presented in Figure 5 and 6.There is increase in the UCS value for all the tests up to 30% to 40% and further decreases.This indicates that the quantity of Fly Ash unto optimum content can induce pozzolanic reaction and cemented materials effectively contributing to shear strength increase , while the additional quantity of Fly Ash acts as unbounded silt particles ,which has neither appreciable friction nor cohesion ,Causing decrease in strength.[10]

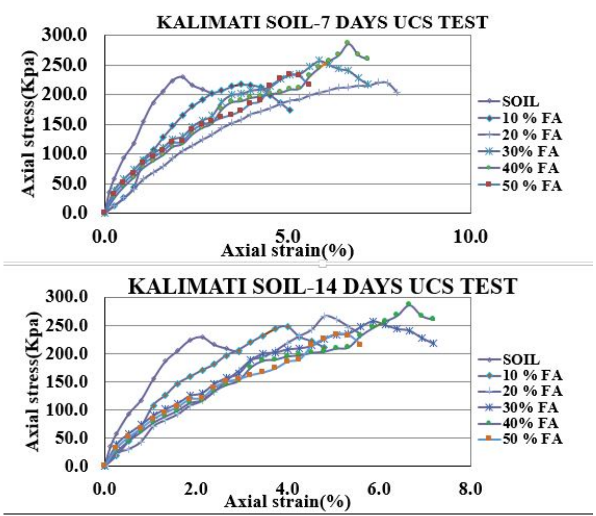

Figure 5: Stress-Strain curve for Kalimati Soil for 7 and 14 days Curing period

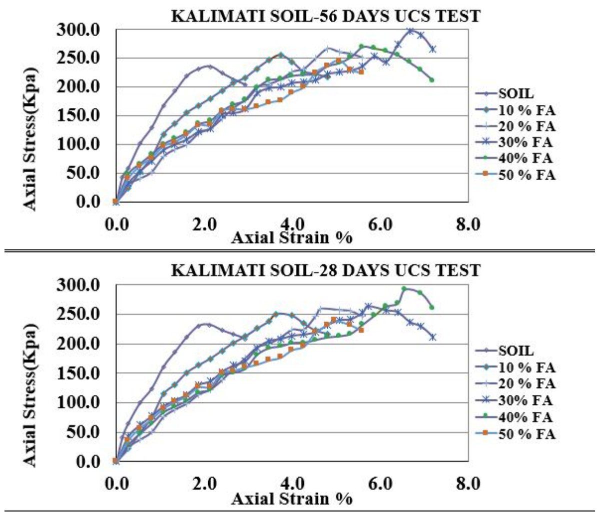

Figure 6: Stress-Strain curve for Kalimati Soil for 28 and 56 days Curing period

5.5 X-ray Diffraction(XRD)

The XRD analysis showed that there were negligible changes in the mineralogy caused by fly Ash addition however there were reductions in the total amount of Clay minerals as shown in Figure 7 and 8

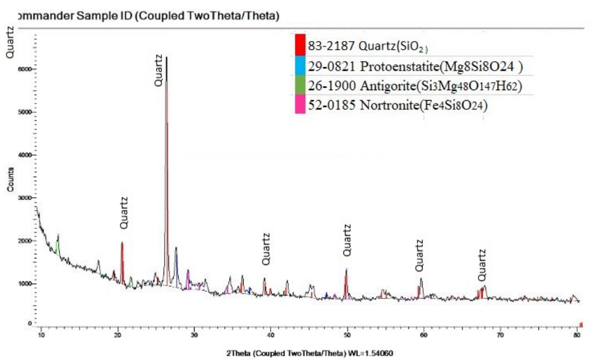

Figure 7: X-ray Diffraction pattern of untreated Kalimati Soil treated

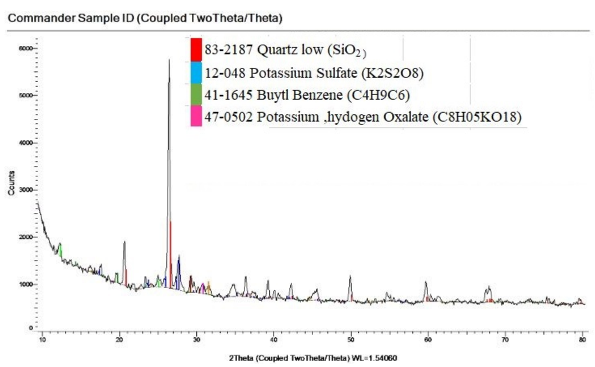

Figure 8: X-Ray Diffraction pattern of Kalimati Soil treated with 20% Fly Ash

6. Conclusions

1. The Liquid Limit of the Kalimati soil with 30% Fly ash has decreased 1.29 times than untreated soil.Further increase in Fly Ash % shows increase in Liquid Limit.

2. The Plastic Limit of the Kalimati soil with 30% Fly Ash has decreased 1.03 times than untreated kalimat soil.

3. The Shrinkage Limit of the Kalimati soil with 30 % Fly Ash has decreased 1.46 times than untreated BC soil.

4. The Free Swell Index (FSI) of the Kalimati soil has decreased by 1.42 times than the untreated kalimati soil .Further addition of Fly Ash has no effect on its FSI.

5. The Maximum Dry density (MDD) of the Kalimati soil has increased 1.14 times for 30% addition of the Fly Ash than untreated Soils.

6. Results Shows that the Peak Compressive Strength for UCS test for 7 days increased by 1.13 times for 40% addition of the Fly Ash than untreated Soils.

7. Results Shows that the Peak Compressive Strength for UCS test for 14 days curing increased by 1.24 times for 30 % addition of the Fly Ash than untreated Soils,1.21 times for 28 days curing and 1.09 times for 56 days curing of the UCS test with decrease in the peak strength with the increased percentage of Fly Ash.
   As a results of all tests and reviews,it shows that the addition of Fly Ash around 30% decrease the swelling and shrinkage properties of Kalimati Soil thereby preventing possible failure of subgrade and overlying structures over them.

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