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EFFECT OF LOW CALCIUM FLY ASH (ASTM CLASS F) ON THE STABILIZATION BEHAVIOUR OF EXPANSIVE SOIL

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Abstract: Expansive soil experiences swelling with the addition of water and then shrink after the removal of water. These alternate wetting and drying impose lot of problems to the structures built on expansive soils. Ground improvement techniques for expansive soil include chemical and mechanical method of soil stabilization. In this paper, chemical stabilization has been used as a ground improvement technique. Testing such as compaction, unconfined compressive strength (UCS) and swell pressure were conducted for expansive soil stabilized with ASTM Class F fly ash as a chemical stabilizer at 8%, 16% and 24% of total weight. Based on the outcome of this study, it was noticed that maximum dry density (MDD) increases up to 16% and then decreases beyond that. Effect of fly ash on variation of UCS value was observed with three different curing periods (7, 28 and 45 days) as well as three different percentages of fly ash (8%, 16%, 24%). UCS values increase up to 16% and then they decrease with any further addition of fly ash. Further, increment of curing period helps to increase the UCS value for a given percentage of fly ash mixture. Reduction of swell pressure was observed with addition of fly ash. On the whole, fly ash can be successfully used as soil stabilized to improve the geotechnical engineering properties of expansive soil.

Keywords: Expansive soil; Fly ash; Maximum dry density; Swell pressure; Uniaxial Compressive Strength.

1. Introduction

Expansive soils subjected to swelling and shrinkage with the absorbing or evaporation of water and therefore, it involves high range of change in volume. Kaolinite, Montmorillonite, illite components in the expansive soil are the major components which undergoes alternative swelling and shrinkage behavior (Hansgeorg, 2006). Low bearing capacity, high settlement, less shear strength and heaving are major problems encountered when construction works are going on expansive soils. Soil stabilization techniques are used to mitigate unfavorable conditions associated with expansive soils and these techniques are categorized into mechanical and chemical methods. Mechanical methods consists soil replacement technique, vibroflotation etc. while chemical methods stabilize soil by adding different chemical compounds such as lime, fly ash, cement etc.(Somaiya et al,2013).

Fly ash is a solid waste which is generated in coal power plants after the combustion of coal. They cause for several environmental hazards if these solid waste is not properly managed in an effective manner. In Sri Lanka, Norachcholai coal power plant generates about 75000 tons of fly ash annually and some of them are used in cement manufacturing process while keeping remaining fly ash causing environmental pollutant. So, it is a sustainable solution for utilization of fly ash in stabilizing soil. Fly ash can be classified as high calcium fly ash (ASTM class C) and low calcium fly ash (ASTM class F) based on the standards of American Society for Testing and Materials. In this study focuses on chemical stabilization of expansive soil by varying percentage of fly ash by weight as chemical admixture. There are many previous studies by Fusheng et.al ,Estabragh and Pereshkafti, Somaiya et.al,Deng et.al focusing on stabilization of soft soil using different chemical stabilizers by various researchers are summarized below.

Fusheng et.al (2008): studied about the high plasticity silty clay stabilized with fly ash and lime at varying percentages. Atterberg limit test, Free swell test, Compaction tests and UCS tests were performed during the experimental study. Main conclusions of their study were liquid limit decreases with addition of fly ash and lime, MDD and OMC decreases with addition of additives. Finally UCS value of tested samples were increased with ash addition up to an optimum and beyond the it decreases with fly ash and lime addition due to the enhanced rate of pozzolanic reaction and flocculation in the stabilized soil mix.

Estabragh and Pereshkafti (2012): A similar comparative study was carried out on high plasticity clay using lime, cement and coal ash as chemical stabilizers. They studied the effect of cyclic wetting and drying as well as compaction characteristics investigated. Main conclusions of this study were liquid limit and plasticity index can be increased with coal ash and cement content, MDD and swelling can be reduced up on addition of additives. Lime and cement showed equilibrium state after 2nd cycle and 4th cycle respectively. Somaiya et. al (2013) :Expansive soil causes for major problems such as heaving when constructions are going on soft ground. In this study, expansive clay stabilized using fly ash as chemical stabilizer. Variation of Atterberg limits, variation of MDD and OMC, variation of UCS with addition of fly ash investigated during this study. Main conclusions were liquid limit and plastic limit reduces with fly ash addition. MDD value of the stabilized soil sample initially decreased to a minimum value and then increased any further ash addition. UCS values of the tested samples initially increases up to an optimum value and then it reduces.

Deng et al (2007): Comparative study using sewage sludge ash and class F fly ash on low plasticity silty clay was done. Mainly pH value test and UCS test carried out during the experimental study. They revealed that, UCS values of soil sample stabilized with fly ash mixture is less than sludge ash treated soil samples due to the variation of chemical composition of fly ash and sludge ash. It is observed that fly ash treated soil samples have much higher pH than soil stabilized with sewage sludge ash. Finally, main conclusion is, fly ash can effectively be substituted by sewage sludge ash in soil stabilization. Laxmikant and Tripathi (2013): Ground granulated blast furnace slag (GBS) and fly ash used to stabilize high plasticity silty clay. Variation of California bearing capacity (CBR) and compaction characteristics studied and key findings of their study were CBR value of the mixture reduces with fly ash and GBS addition. Results indicate that MDD value increases with GBS content while keeping fly ash content constant in the mixture and OMC increases with fly ash and GBS simultaneously.

To date there are very limited studies focusing on the stabilization behaviour of ASTM Class F fly ash to improve expansive soil, and hence major aim of this research is to study the geotechnical engineering properties of expansive soil treated with fly ash.

2. Materials and Methodology

In this study, fly ash is used to stabilize expansive soil which is obtained from Nikkakatiya, Digana, Sri Lanka while fly ash were provided by Holcim Lanka Ltd, Colombo, Sri Lanka. Expansiveness of soil was determined by conducting free swell test. Test result illustrates that free swell ratio is 1.55 and soil is moderately expansive soil according to the classification by Holtz and Gibbs in1956.Gradation of natural soil is shown in Figure 1 and chemical composition of fly ash is shown in Table 1.

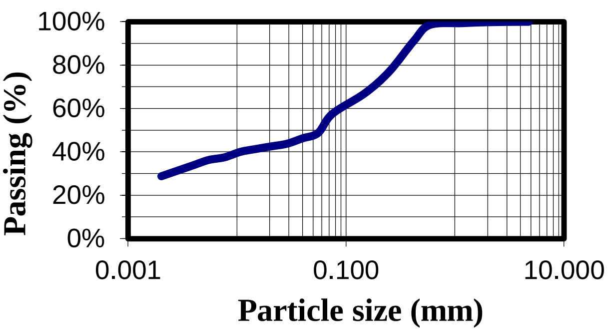

Fig01.Particle size distribution of expansive soil

Table 01. Chemical composition of fly ash

Composition	Percentage by weight
SiO_2	52.03
Al_2O_3	32.31
Fe_2O_3	7.04
CaO	5.55
MgO	1.3
SO_3	0.07
K_2O	0.68
Na_2O	0.43

According to the gradation curve which is depicted in Figure 1, Soil can be classified as clayey soil sample. Soil samples for testing were prepared at 8%, 16%, 24% fly ash by weight with expansive soil after mixing thoroughly. To study the variation of MDD and OMC with fly ash content, A series of standard proctor compaction tests were done for each mix composition according to BS 1377, 1990 part 4. Variation of compressive strength of stabilized soil was observed by conducting a series of UCS tests according to BS 1377, 1990 part 7 and samples for this test were prepared at by compacting to MDD and OMC. Height of 76 mm and diameter of 38 mm samples were prepared while keeping aspect ratio is to 2. Samples were cured at ambient temperature (25 0C) for 7, 28, 45 days and tested for each curing period. For each data point three samples were tested to ensure reliability of test results. Swell pressure test was done according to BS 1377, 1990 part 5 and constant volume test was conducted to identify swelling behavior of stabilized soil samples.

3. Results and Discussion

3.1 Compaction Characteristics

Standard proctor compaction test was done for natural expansive soil, fly ash treated soil samples to study the variation of MDD and OMC with addition of fly ash as chemical admixture. The variation of MDD is shown in Figure 2.

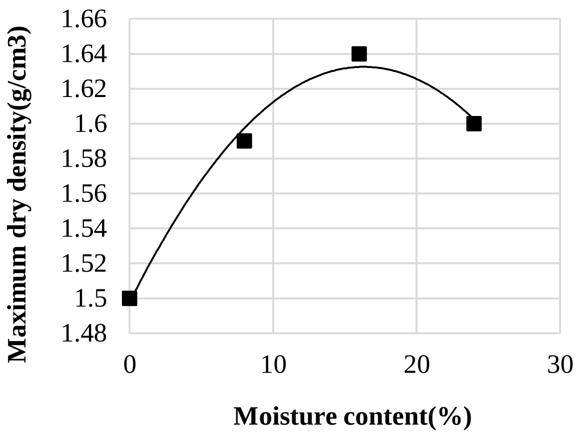

Fig 02. Variation of MDD with fly ash

Based on Figure 2, Initially MDD value is increased up to 16% ash content optimum value of a MDD can be achieved at 16% fly ash content and it is mainly due to flocculation with in soil sample caused by fly ash and well packing of soil particles also leading to the increment of MDD (Phanikumar ,2009). Beyond the optimum it decreases up to 24% fly ash content due to unreacted fly ash particles in the mix and lower specific gravity fly ash particles replacing soil particles causing resulting mix which is having a lower specific gravity.

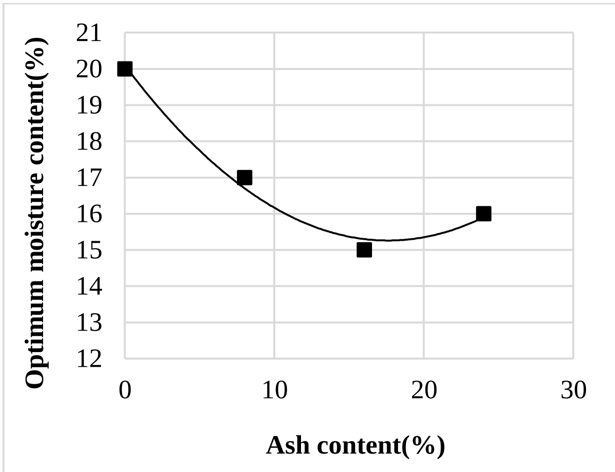

Fig. 03. Variation of OMC with fly ash

The variation of OMC with fly ash content is illustrated in Figure 3. Initially, OMC value decreases up to a 16% fly ash content and the cause for the reduction of moisture content up to a minimum value is mainly due to the cation exchange between additives. After OMC reaches to a minimum value, it starts to increase for any increase in

OMC beyond the optimum. This kind of behavior can be seen because unreacted fly ash particles absorb more moisture and it leads to increment of OMC (Fusheng et al., 2008).

3.2 Unconfined Compressive strength

This test was performed to identify variation of UCS value with fly ash content and standard deviation of UCS values were 0-8%.Variation of UCS value with fly ash addition is shown in Figure 4.

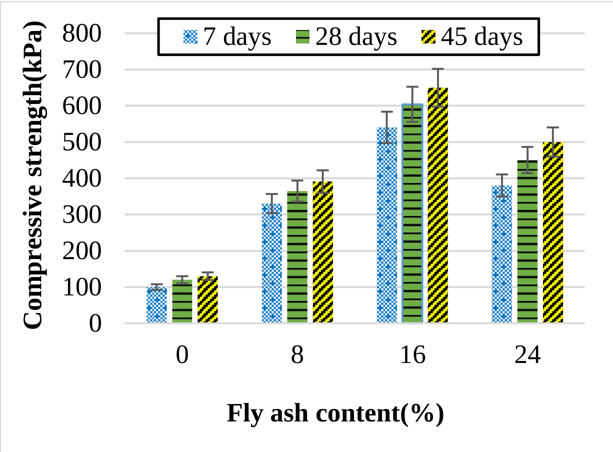

Fig. 04. Variation of UCS with fly ash

Based on Figure 4, UCS value initially increases up to 16% fly ash content and maximum increment is 540% for fly ash treated expansive soil sample at 45 days curing time. It is mainly due to the enhanced pozzolanic reaction and flocculation in the stabilized soil sample. Beyond the optimum, it reduces with ash content due to additional fly ash in the mix act as unbounded silt particles causing decrease in strength (Fusheng et al., 2008).

3.3 Variation of swell pressure

Series of swell pressure tests were conducted to investigate swelling behaviour of stabilized soil with fly ash as chemical admixture. Variation of swell pressure with ash content is shown in Figure 5.

According to figure 5, It can be seen that Swell pressure is decreased to 33 kPa from 113 kPa while adding more and more fly ash to expansive soil. Reduction of swell pressure is

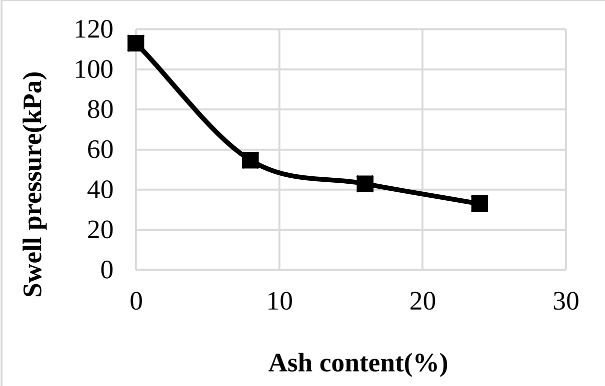

Fig. 5. Variation of swell pressure with fly ash

mainly caused by enhanced pozzolanic reaction and high surface area of fly ash particles. Formation of Calcium Silica Hydrate (CSH) and Calcium Alumina Hydrate (CAH) also helps to decrease in swell pressure (Fusheng et al., 2008)

4. Conclusions

The following points provide important conclusions derived from this study on expansive soil,

- According to standard proctor compaction test results MDD value is initially increased to an optimum value and beyond that decreases. OMC value also decreases to a minimum value and after reaching to the minimum value it starts to increase. This shows that soil and additive mixture can be compacted with lower water content.
- UCS value of the treated soil is increased up to 16% and came to an optimum value. Highest UCS value can be seen at 45 days cured sample. Beyond the optimum UCS value starts to decrease. Reason for the increment of UCS is flocculation and enhanced pozzolanic reaction there of formation of cementitious materials such as CSH, CAH. Reduction of UCS caused by unreacted fly ash particles in the stabilized soil.
- Swell pressure is significantly reduced using fly ash as the chemical additive and it is due to the

pozzolanic reaction and higher surface area of fly ash particles.

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References

[1]. Bell F.G (1996), Lime stabilization of clay minerals and soils, Engineering Geology, vol 42:pp 223–237.

[2]. Deng-Frong L., Kae-LIong L., Huan-Lin L. ,(2007) Comparison between sludge ash and fly ash on the improvement in soft soil , ." Journal of the Air & Waste Management Association 57.1 : pp 59-64.

[3]. Dujang B. Huat ,David G toll,Arun Prasad Handbook of tropical residual soils engineering edition 2012,CRC press: pp 139

[4]. Fusheng Z., Songyu L, Yanjun D., Kerui C. (2008), Behavior of expansive soil stabilized with FA, Natural hazards,vol 47(3), pp.509-523

[5]. Hansgeorg K, Berhane G, Excavations and Foundation in soft soils, Edition 2006, pp 11

[6]. Holtz, W. G. and Gibbs, H. J. (1956), Engineering properties of expansive clays,Transactions ASCE 121,pp 641-677

[7]. Laxmikant Y., Tripathi R.K. (2013), Stabilization of soft soil with granulated blast furnace slag (GBS) and fly ash (FA),." International Journal of Research in Engineering and Technology 2.2 (2013): 115-119.Journal of Pavement Engineering 14.4: pp 418-427

[8]. Phanikumar B. (2009), Effect of lime and FA on swell, consolidation, and shear strength characteristics of expansive clay. Comparative study, Geomechanics and Geoengineering international journal,vol 4.2 : pp 175-181.

[9]. Priyadarshena T, Dissanayake R, Mendis P. (2015), Effect of nano silica, micro silica, FA and bottom ash on compressive strength of concrete, Journal of Civil Engineering and Architecture vol 9 : pp 1146-1152

[10]. Sivapullaiah, P.V. Prashanth, J.P. Sridharan A.(1996) ,effect of FA on the index properties of black cotton soil,soils and foundations vol. 36 (1996) no. 1 :pp 97-103

[11]. Somaiya P, Zala Y, Dangar R (2013); Stabilization of expansive soil using FA; Conference paper