Geotechnical Engineering Properties of Fly Ash and Well Graded Sand Treated Peat

S. Venuja, S. Mathiluxsan
Department of Civil Engineering, University of Peradeniya, Sri Lanka

ABSTRACT: Peat is a kind of soft organic soil having partially disintegrated plant remains hence it is not good for constructions. Chemical stabilization is the commonly used ground improvement technique by adding chemical admixtures such as ordinary Portland cement, fly ash, natural fillers etc. Our research focused on stabilizing peat using a combination of fly ash and well graded sand. An experimental study was conducted to analyse the stabilization of peat with 125 kg/m^3 dosage of well graded sand and fly ash at three various proportions 10, 20 and 30 % by weight. A series of experiments including Unconfined Compressive Strength (UCS) and Rowe cell test were conducted to evaluate the compressibility behaviour of stabilized peat. UCS increases up to 10 % fly ash addition and increases with curing period for all sample types. There is an improvement in settlement behaviour of peat after the above stabilization.

1 INTRODUCTION

Peat lands cover nearly 400 million ha of earth [Bujang et al (2005)]. Low bearing capacity, high compressibility, low specific gravity, high moisture content and difficult accessibility are the main characteristics of peat [Roslan et al (2008), Kolay et al (2011)]. Peat poses serious problems in construction due to the massive primary and long term settlement when subjected to even moderate load [Roslan et al (2008)]. Hence, it is not suitable for foundations at its natural state. Peat is classified according to Von post scale system between H1 (completely fibrous peat) and H10 (completely amorphous peat) based on the degree of humification [Bujang et al (2011)].

Mechanical method and chemical method are the commonly used improvement techniques in stabilizing the soft grounds before construction. Mechanical method includes pre-loading, displacement and replacement, stone columns, vertical drains and paper drains [Bujang et al (2011), Kolay et al (2010)]. Deep mixing method is a chemical stabilization technique by adding chemical admixtures such as sand, fly ash, lime, cement, etc with peat [Bujang et al (2005), Kolay et al (2010)]. The following parts summarize the findings of studies focusing on the stabilization of peat.

Bujang et al (2005) compared the effectiveness of lime and cement on peat stabilization and found that the cement has better interaction with peat than lime because of its quick pozzolanic reactions. Roslan et al (2008) proved that the bearing capacity of stabilized peat improved by 86 % after stabilizing with cement, bentonite, sand and calcium chloride using cone penetrometer test. Kolay et al (2011) investigated the compression behaviour of peat stabilized with pond ash by conducting several unconfined compressive strength (UCS) tests. Optimum moisture content (OMC) decreases and maximum dry density (MDD) with the pond ash addition due to the consumption of pore water during the hydration process. UCS increases with the added pond ash amount as well as with the curing period due to flocculation and hydration process respectively.

Bujang et al (2011) did both experimental study using Rowe cell and numerical study using PLAXIS 2D software to find out the change in compressibility behaviour of peat stabilized with cement. They found the effect of cement is higher on sapric peat due to the higher cation exchange capacity. Kolay et al (2010) observed that 6 % and 20 % of gypsum and fly ash respectively are the optimum content that gives higher UCS values after the stabilization of peat. Ali et al (2013) conducted a study of stabilization of peat with cement and various types of natural fillers to find out the optimum filler content. They found well graded sand is the best filler giving good improvement to peat and the optimum dosage is 125 kg/m^3.

In Sri Lanka, annually 150 metric ton of fly ash is produced in Nuraicholai coal fired power plant and only about 20 % is usable for cement production, leaving huge amount of fly ash ends up in landfills. Thus in this research, chemical stabilization using a combination of fly ash and well graded sand was done. The fly ash will interact with peat soil particles and enhances the geotechnical engineering properties of raw peat. Index properties tests, UCS test and Rowe cell test were conducted to find out the improvement in compressibility behaviour of peat after stabilization using ASTM class F fly ash and well graded sand.

2 MATERIALS AND METHODOLOGY

2.1 *Materials*

Peat sample was collected at Thorana, Kelaniya, Sri Lanka and it was like slurry. Fly ash was collected at Holcim Lanka Ltd, Puttalam, Sri Lanka. It contains more than 70 % of weight of SiO_2 + Al_2O_3 + Fe_2O_3 so that, it is classified as class F (ASTM 618). Table 1. shows the composition of fly ash used in this research. Well graded sand was collected and prepared by adding sufficient amount of particles with various sizes according to ASTM D 2487-83. It should have coefficient of uniformity (C_u) greater than 6, and coefficient of curvature (C_c) between 1 and 3. It was found that C_u is 9.23 and C_c is 1.16 for the well graded sand used in this study.

Table 1. Fly ash composition

Constituents	Percentage / (%)
SiO_2	52.03
Al_2O_3	32.31
Fe_2O_3	7.04
CaO	5.55
MgO	1.30
SO_3	0.07
K_2O	0.68
Cl	1.00

2.2 *Sample Preparation*

Due to the slurry like behaviour, peat was oven dried for two days and sieved through 4.75 mm sieve to remove the objects like roots, stones, etc. The dosage of well graded sand was fixed at 125 kg/m^3 [Ali et al (2013)]. Fly ash was added in three various proportions 10, 20 and 30 % by weight. Five different types of samples were prepared as following: (i) Raw peat (P) ; (ii) Peat + Well graded sand (PSF0) ; (iii) Peat + Well graded sand + 10 % fly ash (PSF10) ; (iv) Peat + Well graded sand + 20 % fly ash (PSF20) ; and (v) Peat + Well graded sand + 30 % fly ash (PSF30).

2.3 *Experimental procedure*

Index properties tests such as Atterberg limits test (BS1377:Part2:1990), Small Pyknometer test (BS1377:Part 2:1990) and Loss on ignition test (BS1377:Part 3:1990) were conducted in order to find out the bulk density, moisture content, specific gravity, liquid limit, plastic limit and organic content of raw peat.

Unconfined compressive strength test (BS1377:Part 3:1990) was conducted at 7 and 28 days of curing for all type of samples. A constant strain controlled loading rate of 0.7 ± 0.1 mm/min was maintained for all tests. 38 mm diameter and 76 mm depth samples were prepared and allowed for air curing. At least two samples were tested and average results were taken as UCS values. Samples also tested to find out UCS values immediately after preparation as control samples. Fig. 1 shows the UCS samples at air curing stage and Fig. 2 shows the UCS apparatus with loaded peat sample.

Fig. 1 Air curing of UCS samples

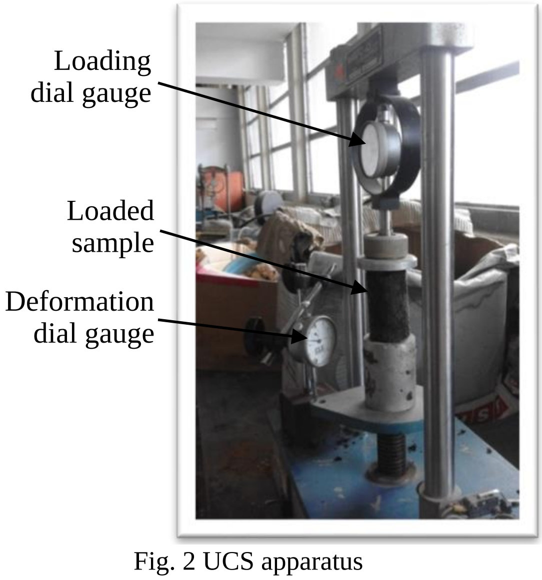

Fig. 2 UCS apparatus

In Rowe cell test, equal strain condition was maintained and one-way top vertical drainage was allowed. The sample size was 151.8 mm diameter and 50 mm depth. The applied consolidation pressures were 50, 100 and 200 kPa. First, de-aired water was poured at the base and porous plate was inserted. Then the sample was placed on the porous plate. After pouring some de-aired water on the top surface of the sample, filter paper was laid on it. Diaphragm balloon was partially filled with water and positioned on top of the filter paper. All bolts and nuts were fixed simultaneously. Dial gauge was set vertically to readout the settlement of the sample. Diaphragm balloon was filled with water completely. The diaphragm pressure line, the drainage line and the pore pressure transducer were connected to the Rowe cell apparatus. Fig. 3 shows the Rowe cell testing apparatus.

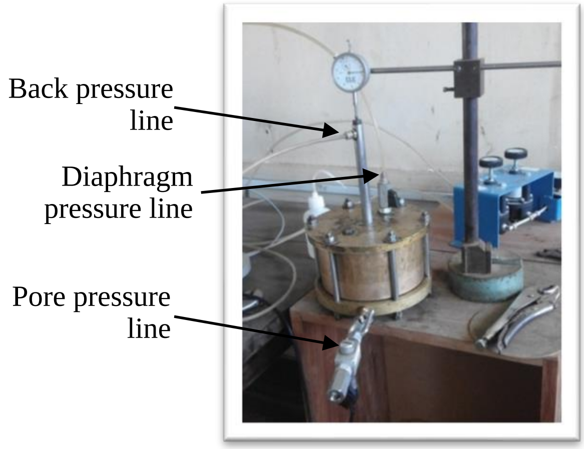

Fig. 3 Rowe cell apparatus

Initially, 10 kPa back pressure was applied to the sample and waited until the pore pressure reaches to 10 kPa to ensure the completion of the saturation. Then the drainage valve was closed and 50 kPa diaphragm pressure was applied. Dial gauge was set to zero after the increase in pore pressure equals the applied diaphragm pressure. Drainage valve was then opened and stop watch was activated simultaneously. The dial gauge reading and the pore pressure reading were taken with corresponding time. These procedures were repeated for other two diaphragm pressure values (100 kPa and 200 kPa).

3 RESULTS AND DISCUSSION

3.1 *Index properties of raw peat*

Based on the tests conducted, raw peat has the following properties: bulk density of 1055 kg/m^3, moisture content of 102 %, specific gravity of 1.90, organic content of 83.7 %, liquid limit of 101.2 % and non-plastic. Based on these results, peat is classified as amorphous peat [Youventharan et al (2007), Sina et al (2011)].

3.2 *UCS results*

Figure 3 shows the UCS test results. UCS increases with curing period for all types of sample, due to the pore water consumption is high as fly ash particles produce cementing materials throughout the hydration process [Kolay et al (2011)]. There is an initial increase in UCS up to 10 % fly ash addition, because of the air voids in peat were filled with finer fly ash particles [Kolay et al (2011)]. UCS reduces as more fly ash added to the mix. This is due to the un-reacted fly ash particles in the mix [Kolay et al (2011)]. From these results, it is found that the optimum mix proportion of fly ash is 10 % that gives good compressibility behaviour improvement to raw peat.

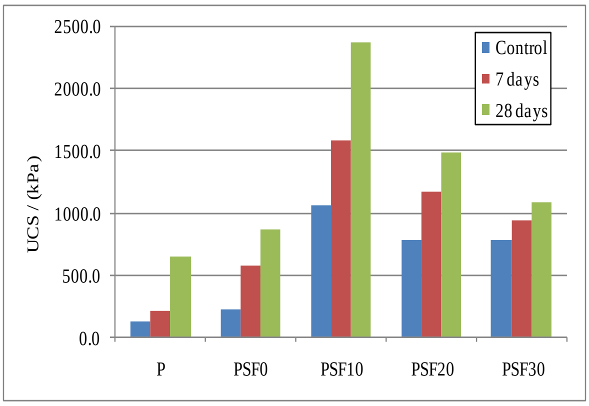

Fig. 4 UCS test results

3.3 *Settlement behavior*

Rowe cell test was conducted for raw peat and the peat stabilized with 10 % fly ash content which gives the highest UCS. Fig. 4 shows the settlement variation with time of both samples with various consolidation pressures. There is more than 50 % settlement reduction after stabilization of peat using 10 % fly ash and well graded sand for all consolidation pressures. Therefore, the settlement behaviour of peat improved after the stabilization. Fig. 5 shows the variation of void ration with the applied consolidation pressure for both samples. From the slope of these curves, compression index (C_c) of peat and stabilized peat with 10 % fly ash were obtained [Eq.(1)]. Compression index of raw peat was 0.548 and stabilized peat with 10 % fly ash was 0.149. There is no secondary consolidation after the stabilization. It shows the improvement in the compressibility parameters after stabilization and it is due to the flocculation of fly ash particles with soil particles [Phanikumar (2009)].

$$C_c = (e_2 - e_1) / \log (p_2/p_1) \qquad (1)$$

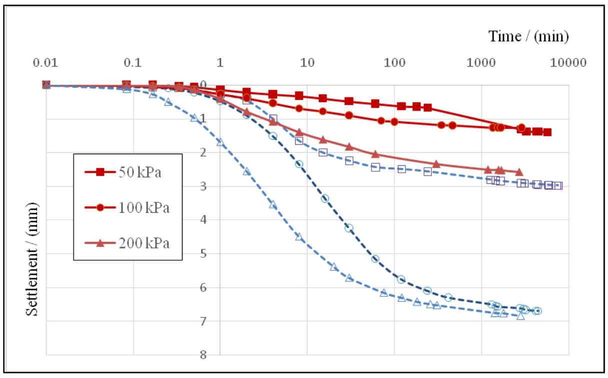

Fig. 4 Settlement variation with time of raw peat (hollow line) and stabilized peat with 10 % fly ash (solid line)

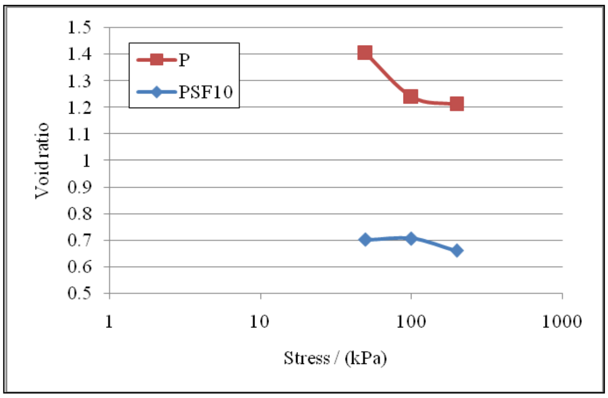

Fig. 5 Variation of void ratio with stress

4 CONCLUSIONS

In order to study the compressibility behaviour of stabilized peat with ASTM class F fly ash (0 - 30 % by weight) and well graded sand (125 kg/m^3), an experimentally based study was conducted. The following conclusions were made. The type of peat used in this research is amorphous. The optimum mix composition is peat + well graded sand + 10 % fly ash, as it gave the highest UCS value. The UCS of stabilized peat with 10 % fly ash was nearly 7 times of the UCS of raw peat. UCS also increased with the curing period. Based on Rowe cell test results, it is found that there is an improvement in compressibility behaviour and consolidation parameters after the stabilization of peat using class F fly ash and well graded sand. On the whole, this study results may be used in improvement of peat lands using deep mixing method. Fly ash may be added in powdered form into peat soil by dry mixing method since peat has high water content.

ACKNOWLEDGMENTS

We would like to thank all people who helped us to successfully complete our research. Especially, we wish to thank Dr.M.C.M.Nasvi (Lecturer of Civil Engineering, Department of Civil Engineering, University of Peradeniya, Sri Lanka), our project supervisor, who gave guidance and support in developing ideas on this research.

REFERENCES

Ali D, Kamarudin A, Nazri A 2013. Influence of natural fillers on shear strength of cement treated peat: GRADEVINAR 65, Vol 7, 633-640.

Bujang B.K.H, Shukri M, Thamer A.M 2005. Effect of Chemical Admixtures on the Engineering Properties of Tropical Peat Soils: American Journal of Applied Sciences 2, Vol 7, 1113-1120.

Bujang B.K.H, Sina K, Arun P, Maassoumeh B 2011. A study of the compressibility behavior of peat stabilized by DMM: Lab Model and FE analysis: Scientific Research and Essays, Vol 6(1), 196-204.

Kolay P.K, Pui M.P 2010. Peat Stabilization using Gypsum and Fly Ash: UNIMAS E-Journal of Civil Engineering, Vol 1.

Kolay P.K, Sii H.Y, Taib S.N.L 2011. Tropical Peat Soil Stabilization using Class F Pond Ash from Coal Fired Power Plant: International Journal of Civil and Environmental Engineering 3, Vol 2, 79-83.

Phanikumar B.R 2009. Effect of lime and fly ash on swell, consolidation and shear strength characteristics of expansive soils: a comparative study: Geomechanics and Geoengineering, Vol 4(2), 175-181.

Roslan H, Shahidul I 2008. Properties of Stabilized Peat by Soil-Cement Column Method: Bund. J, Vol 13.

Sina K, Arun P, Bujang B.K.H, Jafar B.B, Farah N.A, Abdul A, Mohammad A 2011. Influence of Cement – Sodium Silicate Grout Admixed with Calcium Chloride and Kaolinite on Sapric Peat: Journal of civil engineering and management, Vol 17(3), 309-318.

Youventharan D, Bujang B.K.H, Azlan A.A 2007. Engineering Properties and Compressibility Behavior of Tropical Peat Soil: American Journal of Applied Sciences 4, Vol 10, 768-773.