Use of Paddy Husk Ash as a Binder in Improvement of Soft Peaty Clay

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ABSTRACT: Ground improvement in soft soils through pre-consolidation by preloading with or without vertical drains or vacuum consolidation has the main drawback of time consumption. Deep mixing with the cement is an alternative solution that has been studied and it was found that cement percentages of 20-30% are required to obtain a sufficient level of improvement. In view of the high cost involved the study of the use of paddy husk ash (PHA) also known as Rice Husk Ash (RHA)-another pozzolonic material which is a waste product of rice production has been conducted. Improvement through mixing natural peat with different proportions of cement and PHA was studied in this project. Engineering properties of samples comprise with different mix proportion of cement and PHA were compared with samples of untreated peat. Improvement in compressible characteristics and shear strength were evaluated through performing one dimensional consolidation test and undrained triaxial test.

1 INTRODUCTION

Rapid development in construction industry in Sri Lanka has caused a high demand for sites with suitable soil conditions. Most of the desirable land areas were occupied already and the outcome of this was scarcity of land and increased demand for the natural resource lead to inability of obtaining construction sites which will meet the design requirements in most geotechnical projects without any ground modifications.

Mechanical and chemical stabilization methods were used for improving the soil strength and obtaining modified lands. Of those methods chemical stabilization method where soil stabilization depends mainly on the reaction between stabilizer and soil mineral was very commonly used for soft soil stabilization. Cement, lime, fly ash, blast furnace slag, etc. are the most commonly used binders.

Cement is one of the most favoured materials as a binder but limited in widespread use in stabilization projects due to economic concerns. Hence most researchers tried to find an economical solution for soil stabilizing. Paddy husk ash, a byproduct of rice generation, was the one of the least expensive and highly favorable solution for the problem that existed.

The components of stabilization technology include soils and or soil minerals and stabilizing agent or binders (cementitious materials) (Makusa 2012).

Being a cement replacement materials, rice husk ash can help to reduce considerably the required amount of ordinary Portland cement to achieve the same strength in the case of cement only. With a fixed amount of cement, added rice husk ash can improve largely the strength (Vinh 2012).

The compressibility characteristic is the most prominent parameter when we consider construction on soft soils. A study by Chandrasiri, Priyankara, and Madhusanka (2012) showed that mixing peaty clay with 20% cement and 20% PHA, primary consolidation characteristics as indicated by C_c or m_v were enhanced and secondary consolidation characteristics as indicated by C_α decreased significantly.

Therefore attempts are made in this research to identify the possibility of using paddy husk ash by itself and together with cement to improve engineering characteristics of peaty clay.

2 PREPARATION OF SAMPLES

Samples were prepared by mixing peaty clay with cement and PHA with a hand mixer in the laboratory. In order ensure a uniform level of mixing in all cases, similar mixing speeds and mixing durations were used and mixing was done with small quantities. Mix was placed in buckets and left for 28 days under submerged conditions and under surcharge of $10 kN/m^2$. As a control sample peaty clay was remoulded and kept to settle for 28 days under similar surcharge. The basic properties of the five samples after 28 days are summarized in Table 1. Undisturbed specimens were obtained from the five samples to conduct the necessary laboratory tests to determine the strength and compressibility characteristics. Five number of samples were prepared mixing different percentages of cement and PHA.

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Table 1. Description of samples

Sample No	Mix proportion
S1	Cement 30%
S2	Cement 20% PHA 10%
S3	Cement 10% PHA 20%
S4	PHA 30%
S5	Peat only

Table 2. Sample properties

Basic property	Moisture content %	Specific gravity	Initial void ratio	pH value at 25^0C
S1	117	1.68	1.96	9.4
S2	143	1.67	2.39	8.8
S3	142	2.00	2.84	8.2
S4	198	1.51	2.99	3.6
S6	188	1.98	3.72	2.1

3 COMPRESSIBILITY CHARACTERISTICS

The Oedometer testing apparatus was used to determined compressibility characteristics of treated and untreated peaty clay. Laboratory consolidation tests were conducted by loading, unloading and reloading with different stresses increments. The effects on the parameters corresponding to primary and secondary consolidation were analyzed separately.

Loading/ unloading was done once in three days specially to concentrate on secondary consolidation characteristics. Tests were done with loading increments of 5, 10, 20, 40, 80, 160, 320 and 640kN/m^2. After unloading to a stress level of 10kN/m^2, specimens were reloaded through increments of 20, 40, 80, 160, 320, and 640 kN/m^2.

3.1 *Changes in e vs log (σ) relationship*

Table 3. Data obtained from e Vs log (σ) plots

Sample	Cc	Cr	Cc/1+e_0
1	0.111	0.046	0.038
2	0.219	0.056	0.065
3	0.296	0.064	0.078
4	0.334	0.099	0.083
5	0.387	0.056	0.054

Changes in the primary consolidation characteristics were illustrated through e vs log σ plots. The plots for all samples are presented in Fig. 1. The basic consolidation characteristics are compared in Table 3. It could be clearly see in Figure 1 that initial void ratio is reduced with the mixing of cement or PHA. Mixing with 30% of cement, S1 provided the maximum improvement. Mixing with 30% PHA alone, S4 provided the least improvement. Mixing of a smaller amount of cement together with PHA to compensate in S2 and S3 provided better improvements than mixing PHA alone, but less improvement than the use of 30% cement.

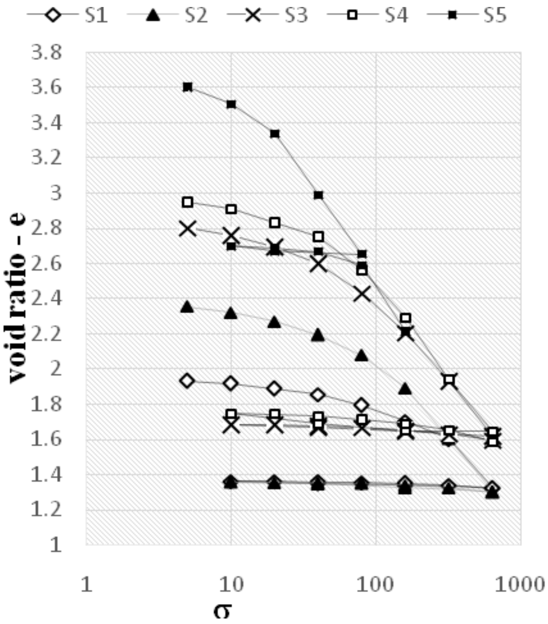

Fig. 1 e vs log σ plot for treated and untreated peaty clay samples

3.2 *Changes in coefficient of volume compressibility*

Coefficient of volume compressibility is an alternative parameter for estimating settlement. It is evaluated at different stress levels. The influence

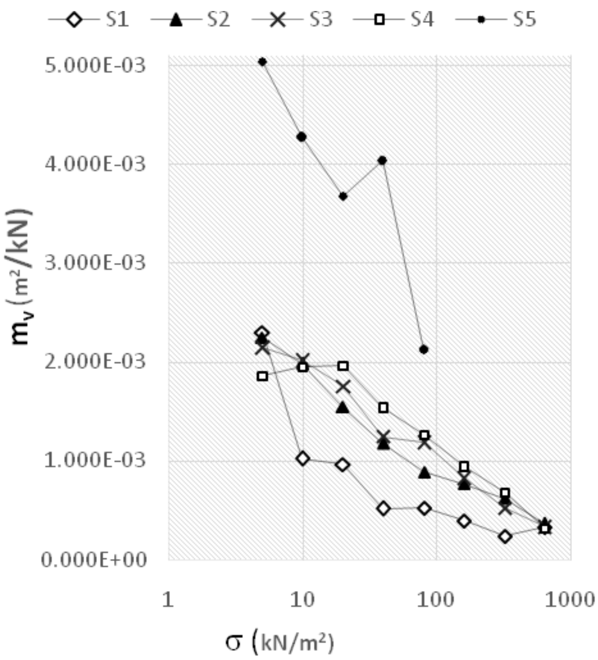

Fig. 2 Effects on m_v plots for loading stage

of mixing with cement or PHA on this parameter is illustrated by the comparison of the parameter for differently treated peaty clay samples in loading stage in Fig. 2.

This result also confirmed that the coefficient of volume compressibility decreased due to mixing with PHA, but the reduction due to mixing with cement was much greater.

3.3 *Changes in coefficient of secondary consolidation (C_α)*

Secondary consolidation is continued creep after complete dissipation of pore water pressure and soft organic soils show large amount of secondary consolidation. The Coefficient of secondary consolidation Cα values were obtained from gradient of the secondary consolidation part of void ratio vs. (log) time curve and presented in Fig. 3.

The results showed that the secondary consolidation coefficient was considerably reduced due to the mixing with cement or PHA. Here also the improvement achieved with mixing of cement was much greater. Use of PHA also caused some improvement but to a lesser extent.

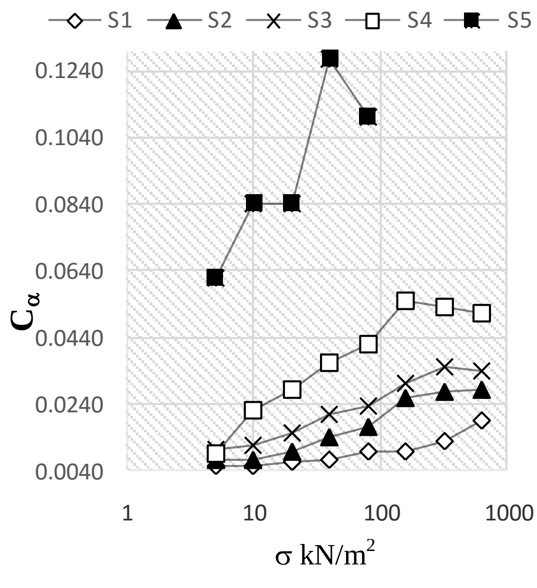

Fig. 3 C_α plots for samples in loading stage

4 CHANGES IN UNDRAINED SHEAR STRENGTH

The other most undesirable engineering characteristic of peaty clay is low shear strength. In construction projects the soft subsoil has to be loaded at a practically acceptable rate to prevent shear failure. In such cases undrained shear strength is the most appropriate parameter in evaluation of stability. Cell pressures of 50, 100 and 150 kN/m^2 were used for testing three specimens from each sample. Continuous increment of axial stress was maintained till failure of the sample occurred. Stress – strain relationship and Mohr circles were plotted for each sample and undrained shear strength parameter (C_u) was evaluated.

Table 4. Values obtained for shear strength

Sample No	Sample description	Average C_u (kN/m^2)
1	Cement 30%	46.67
2	Cement 20% PHA 10%	18.67
3	Cement 10% PHA 20%	19.33
4	PHA 30%	11.00
5	Peat only	5.36

The maximum improvement of undrained shear strength was achieved with mixing of 30% cement. Mixing of smaller amount cement and PHA to compensate the reduction, achieved less improvements.

5 CHANGES IN MICROSTRUCTURE

The changes in the microstructure of peaty clay due to mixing of cement can be illustrated by the comparison of Figure 4 and Fig. 5. The formation of structure can be seen in Fig. 5 where 30% is used With the 30% PHA only similar structure formation was not seen (Fig. 6).

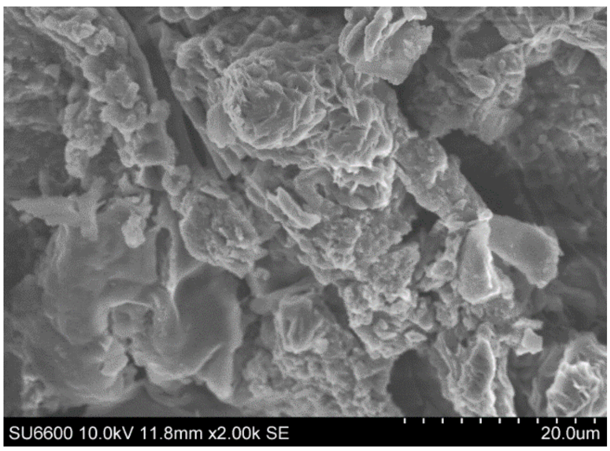

Fig. 4 Microstructure of the natural peat sample

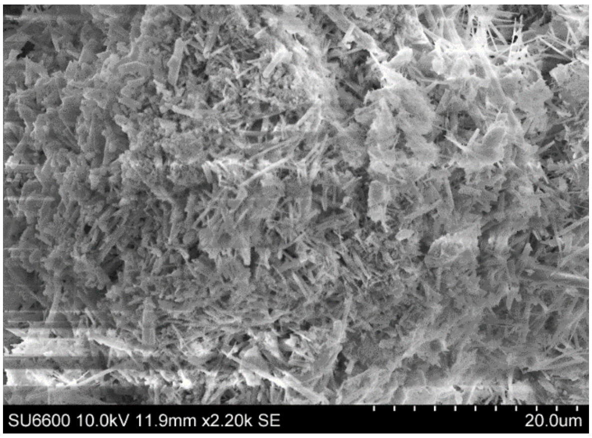

Fig. 5 Microstructure of the peat sample mixed with 30% cement

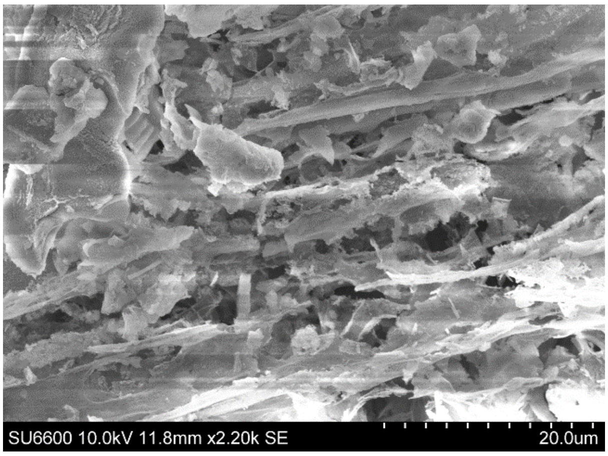

Fig. 6 Microstructure of the peat sample mixed with 30% PHA

6 CONCLUSIONS

Preconsolidation by preloading is the most widely used technique for improvement of soft peaty clay. Even with the use of prefabricated vertical drains the process takes a considerable time. In situations where there are time constraints other techniques such as insitu mixing with cement or other binders have been used. In order to achieve desired level of improvements a cement content of around 30% will have to be used in the improvement of peaty clay. In this research an attempt was made to study whether PHA can replace some amount of cement.

Different percentages of PHA added to peat samples were compared with sample of untreated peat and sample with added cement percentage. As consolidation is the most dominant factor for soft soils Oedometer test was conducted to evaluate compressible characteristics. Undrained Triaxial tests were carried out to evaluate shear strength parameters.

The results of the study showed that the primary consolidation and secondary consolidation characteristics are clearly improved by mixing with PHA and PHA + cement mix. But the improvement achieved through mixing with cement is much greater. Mixing only with PHA did not result in significant improvement.

Improvement in shear strength can be obtained through treating the natural peaty clay. The addition of 30% cement provided the best improvement.

The results showed that to achieve a significant improvement of strength and compressibility a cement percentage of around 20% is needed. PHA percentage of 10% may be added to enhance it further. PHA alone did not cause much improvement.

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