Possible use of Paddy Husk Ash in Improvement of Engineering Characteristics of Peaty Clay

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ABSTRACT: Deferent types of consolidation techniques have been used to improve the engineering characteristics of peaty clays encountered in highway projects in Sri Lanka. The main drawback in these techniques is the long time duration required in the case of thick deposits. Mixing with cement as an alternate improvement technique had been studied at University of Moratuwa successfully in the laboratory. Considering the high cost involved in mixing cement, this research attempts to study the use of another pozzolonic material-paddy husk ash (PHA)(Also known as Rice Husk Ash (RHA) - that is widely available as a waste product. In this research, to assess the improvement of strength and compressibility, different mix proportions were tried out. Improvements were assessed by conducting consolidation tests and unconsolidated undrained triaxial tests. Test results showed that PHA alone is not as effective as cement as a binder but can be used in combination with cement.

1 INTRODUCTION

Geotechnical Engineers in Sri Lanka face the challenge of constructing highways through sites underlain with thick layers of peaty clay. Peaty clay gives rise to enormous geotechnical engineering problems due to; high compressibility and low shear strength. In Sri Lanka several soil improvement techniques based on consolidation such as; preloading with vertical drains, vacuum consolidation combined with preloading have been used successfully in practice. The major drawback in above methods is the long duration required.

If the peaty clay is mixed in-situ with an appropriate binder such as cement, the hydration reactions and the subsequent pozzolonic reactions will cause a major change in the microstructure and considerable gain in strength and stiffness would be achievable within a relatively shorter period of time such as 28 days.

When pore water in the soil reacts with the cement, hydration occurs rapidly and primary cementitious products such as Calcium Silicates, Calcium Aluminates and Hydrated Lime are formed. These particles bind together to form hardened skeleton matrices which enclose unaltered soil particles. Hydration of cement causes a rise of pH value of pore water and Soil Silica and Alumina will be dissolved in this strong bases. These products react with Calcium ions liberated in the process to form insoluble secondary cementitious products. This secondary reaction is known as the pozzolonic reaction. Since some of the calcium ions liberated will be used to satisfy the high exchange capacity of the organic matter, a greater amount of cement is required to stabilize an organic soil. (Maclean and Sherwood 1962).

Laboratory studies done at University of Moratuwa have shown that a cement content of the order of 20-25% is required (Munasinghe 2001, Saputhantiri and Kulathilaka 2011). This is comparable with the cement weights of 200 - 250 kg per cubic meter of treated soils reported in literature (Lahtinen et al 1999). The cost of this treatment would be very high. These binders either in dry powder form or wet grout form are mixed with peaty clay in-situ using appropriate machinery.

Several researchers in recent times have successfully used mixes of cement and various industrial by products such as blast furnaces slag to stabilize both inorganic and organic clays (Jegandan et al 2001). Such industrial by products are not available in Sri Lanka.

Paddy husk is an agricultural waste obtained from milling of rice and it is used to burnt bricks and tiles. In Sri Lanka about 2.2 million tons of rice is produced annually and Paddy husk ash (PHA) is a byproduct of bricks and tiles manufacturing industry. Paddy Husk Ash (PHA) is a pozzolanic material with silica content of 82 – 87 %. The high percentage of siliceous materials in the PHA makes it an excellent material for stabilization.

Therefore attempts are made in this research to study the possibility of using paddy husk ash to improve engineering characteristics of peaty clay. The soil sample used for this study was collected from Southern highway project area.

2 PREPARATION OF SAMPLES

Samples were prepared by mixing peaty clay with 20% of cement, 15%, 20%, 30% of PHA and 15%:15% of cement: 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. As a control sample peaty clay was remoulded and allowed to settle for 28 days. The basic properties of the three samples after 28 days are summarised in Table 1. Undisturbed specimens were obtained from the three samples to conduct the necessary laboratory tests to determine the strength and compressibility characteristics.

Table 1. Sample preparation

Basic Property	Peat (Pt)	20% PHA	20%Cement (Ct)	15% PHA + 15% Ct	15% PHA	30% PHA
Moisture Content%	300	195	135	195	234	253
Organic Content%	22	19	12			
PH Value	4.20	5.12	9.93			
Specific gravity	1.46	1.9	2.03	1.59	1.61	1.65
Initial void ratio	5.56	3.96	2.74	3.09	3.77	4.17

3 COMPRESSIBILITY CHARACTERISTICS

Oedometer tests were conducted to assess the improvements achieved in the compressibility characteristics. Six specimens were tested taking one each from the above mixes. The settlements in the peaty clays are high with both primary and secondary consolidation. Secondary consolidation settlements are very significant in the peaty clay. As such, the effects on the parameters corresponding to primary and secondary consolidation were analyzed separately.

In order to assess the secondary consolidation characteristics the duration of a load increment was increased to 3 days. Tests were done with loading increments of 5, 10, 20, 40, 80 and 160kN/m^2. After unloading to a stress level of 5kN/m^2, specimens were reloaded step by step up to 160 kN/m^2.

3.1 *Changes in e Vs log (σ) Relationship*

Changes in the primary consolidation characteristics were illustrated through e Vs log σ plots. The plots for differently treated peaty clay samples are presented in Fig. 1 and parameters are summarized in Table 2. It could be seen that the use of PHA caused some improvement of primary consolidation characteristics but the improvements were less than that achieved with cement. The use of more than 20% of PHA did not cause any further improvement. The combined use of cement and PHA was also quite effective.

Fig. 1 e Vs σ plots for treated and untreated peat samples

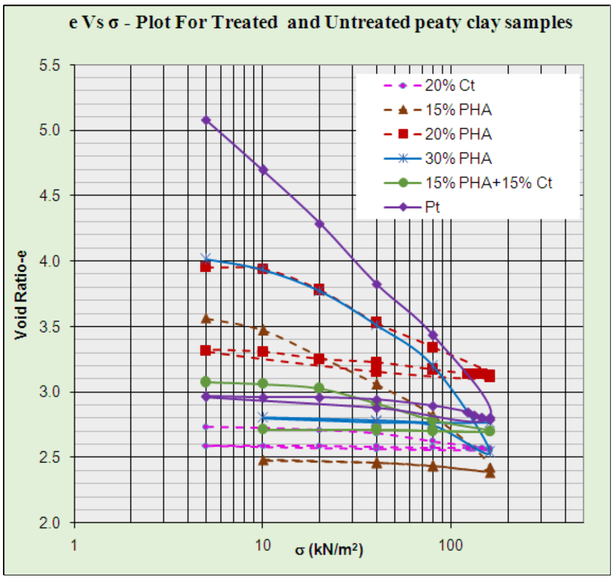

Table 2. Parameters obtained from e Vs log(σ) plots

Sample	C_c	C_r	p_c (kN/m²)	$C_c/(1+e_0)$
PT	1.510	0.117	0	0.248
20% CE	0.209	0.013	40	0.056
15%PHA	0.868	0.078	10	0.156
20% PHA	0.688	0.121	10	0.138
30% PHA	0.950	0.043	10	0.184
15% PHA + 15%CE	0.362	0.023	20	0.088

3.2 *Changes in Coefficient of Volume Compressibility*

The coefficient of volume compressibility is an alternate parameter used to estimate the primary consolidation settlements. It is usually evaluated at different stress levels. The influence of mixing with cement or PHA on this parameter is illustrated by the comparison of the parameter for differently treated peaty clay samples (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. Optimum improvement can be seen in the samples of 20% cement mixed and 15%:15% of cement: PHA mixed samples. It is noted that 30% PHA mixed sample did not show better improvement than 20% PHA mixed sample.

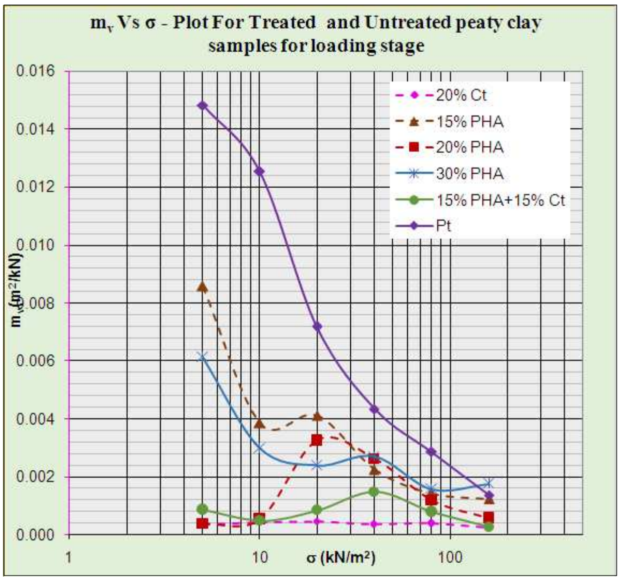

Fig. 2 Variation of m_v with stress level

3.3 *Changes in Coefficient of Secondary Consolidation (C_α)*

Secondary consolidation settlements are generally high in peaty clay and are evaluated through the coefficient of secondary consolidation (C_α). As such, the effect of cement mixing and PHA mixing on the coefficient of secondary consolidation C_α was also studied in detail. The C_α value is the gradient of the graph of e Vs log (time) after the completion of the primary consolidation phase. The values of C_α were determined for each stress level for the five differently treated peaty clay samples are presented in Fig. 3.

The results show that the coefficient of secondary consolidation was considerably reduced due to the mixing with cement or PHA. The reductions achieved were of the same order. In the peaty clay sample the C_α value was increasing with the stress level. This feature was not observed in the samples mixed with either cement or PHA.

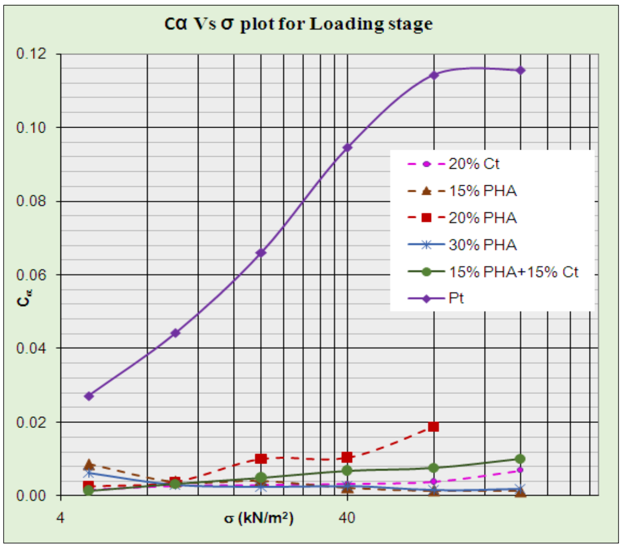

Fig. 3 Variation of C_α with stress level

4 SHEAR STRENGTH CHARACTERISTICS

Peaty clays are of extremely low shear strength and preventing possible shear failure during the construction of embankment on them is a major challenge. Moisture content values in excess of 300% and undrained shear strength values as low as 4 kN/m^2 (or even lower) had been reported in the infrastructure development projects in Sri Lanka. In these projects the embankment filling has to be done at a very slow rate to prevent shear failures during the construction. As such, undrained shear strength is the most appropriate parameter in the evaluation of stability and it was evaluated by unconsolidated undrained triaxial test.

The samples of natural peat were very soft and failed due to its own weight in during the setting up in the laboratory. As such, laboratory vane shear test was used for the peaty clay. The initial moisture contents for the tested specimens of cement mixed and PHA mixed peaty clay are presented in Table 3.

The Mohr circles obtained from the tests are presented in Fig. 4, Fig. 5, Fig. 6 and Fig. 7 and Fig. 8 respectively.

Table 3. Details of samples

	Specimen	Moisture Content	Cell Pressure kN/m^2	Strain at Failure %	Cu kN/m^2
20% Cement mixed Peat Samples	C1	138	50	13.44	30
	C2	132	75	8.96	
	C3	187	125	14.94	
15% PHA mixed Peat Samples	R1	240	50	45.72	7
	R2	242	75	17.78	
20% PHA mixed Peat Samples	P1	184	50	8.96	6
	P2	188	75	10.45	
30% PHA mixed Peat Samples	R1	242	50	25.40	9
	R2	228	75	20.32	
	R3	239	125	13.78	
15% PHA +15% Cement mixed Peat	C1	154	50	20.32	22
	C2	145	75	25.40	
	C3	169	125	33.02	

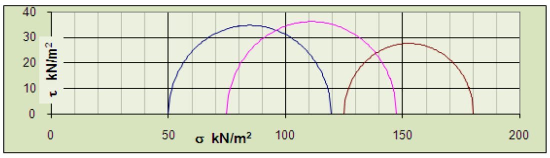

Fig. 4 Mohr circle plot for 20% cement mixed samples

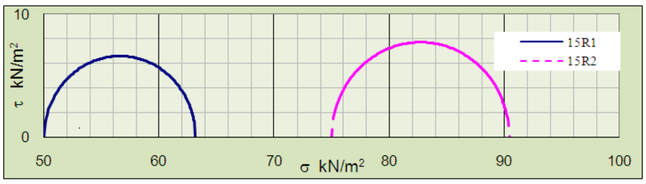

Fig. 5 Mohr circle plot for 15% PHA mixed samples

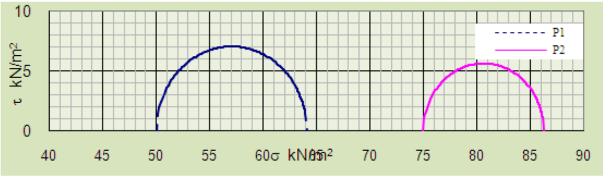

Fig. 6 Mohr circle plot for 20% PHA mixed samples

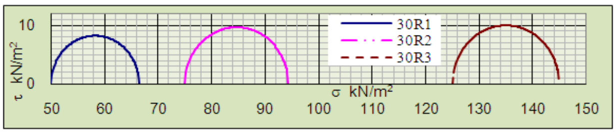

Fig. 7 Mohr circles for 30% PHA mixed samples

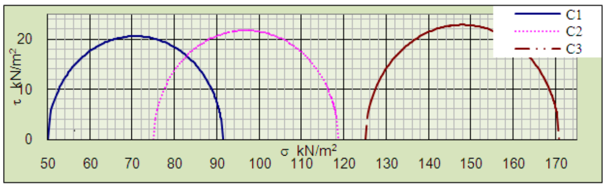

Fig.8 Mohr Circles for 15%:15% cement:PHA

The results obtained by laboratory vane shear test are presented in Table 4.

Table 4. Undrained strength by vane shear test

Sample	Shear Strength (kN/m²)
Peat Only	0.99
20% CE	3.32
20% PHA	40.18

It could be seen that the mixing of PHA and mixing of cement has improved the shear strength. But clearly the improvement achieved by mixing of cement is much greater. Mixing with both 15% of cement and 15% PHA is also shows significant improvement compared with other samples. Also, it should be noted that for the cement mixed peaty clay PHA mixed peaty clay the shear strength values obtained by the UU triaxial test and laboratory vane shear test are somewhat different.

5 CONCLUSIONS

Extremely low shear strength and high compressibility of peaty clays impose many construction problems when embankments are to be constructed on sites underlain by such soils. In many infrastructure development projects in Sri Lanka these problems were overcome by pre-consolidation techniques such as preloading with vertical drains and vacuum consolidation. The major drawback associated with these methods is the duration of the treatment.

With the in-situ mixing of the soft peaty clay with an appropriate binder the pozzolonic reactions can be initiated and the engineering characteristic could be enhanced. This has been very successfully implemented in Japan and many Scandinavian countries.

In this research, attempts were made to use an agricultural by product PHA which is proven to be a pozzolonic material in the improvement of peaty clay.

Samples were prepared by mixing peaty clay with different percentages of cement, PHA anda combination. After leaving the samples for 28 days for the pozzolonic reactions to complete, strength and compressibility of the treated peaty clay were evaluated by laboratory testing.

The results showed that the undrained shear strength improved with the mixing of PHA or cement, but the improvement achieved with the mixing of cement was much greater. Considerable improvement can be seen mixing with both cement and PHA in the proportion of 15%:15%.

Primary consolidation characteristics as indicated by C_c or m_v were enhanced due to the mixing of cement of PHA. There again the improvements achieved with cement mixing was much greater.

The secondary consolidation characteristics as indicated by C_α decreased significantly due to the mixing with cement or mixing with PHA. The improvements achieved were of similar order. In the cement or PHA mixed samples the C_α value did not increase with the stress level. In contrast in the untreated peaty clay C_α value increased with the stress level.

Further tests are currently being done with different combinations of Cement and PHA.

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