STRENGTH DEVELOPMENT IN CEMENT STABILIZED ORGANIC SOILS

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ABSTRACT

This paper presents the strength development and compressibility characteristics of cement stabilized organic soil in Khulna region having the varying organic contents from 10 to 60%. The cement as 20% of dry weight of soil was mixed thoroughly at the water content equal to the liquid limit of used soil. A series of unconfined compression tests were conducted for the curing periods of 1, 3, 7, 14 and 28 days to examine the improvement of strength as well as the stress-strain characteristics with time. The test result reveals that the strength of the cement stabilized organic soil is increased significantly. Finally, an empirical relationship is proposed which can be used conditionally to estimate the compressive strength of cement stabilized organic soils in Khulna region, developed with time.

KEYWORDS: Cement-stabilized, Compressive strength, Organic soils, Strength development, Empirical relationship

INTRODUCTION

Soils are primarily media for any construction work and its bearing capacity is generally governed by its strength and compressibility characteristics (Bowles, 1997). The supporting power of loose or soft organic soil lying close to the ground surface is very low and always leads to use of uneconomical foundation for construction works due to cost involvement for conventional foundation systems in such situations. The inherent limitations of the conventional foundations lead to choosing an alternative solution, namely, ground improvement technique for solving geotechnical problems. Shallow soil cement stabilization and in-situ deep mixing technique (cement column) are widely used for this purpose (Bergado and Miura, 1994). The geotechnical properties of cement stabilized soil largely depends on soil type and composition, type of cementing agent and its quantity, aging, mixing method, mixing water contents, etc. (Suzuki 1982, Nagaraj et al. 1996, Yamadera et al. 1998 and Yamadera 1999). Therefore, to depict the actual behavior of cement stabilized soil in a particular site, the properties should be identified independently by mixing a known cementing agent with the sub-soil of that site (Alamgir and Das, 2003).

The sub-soil conditions in Khulna region, southwest part of Bangladesh consists of recent alluvial deposits and organic composition and hence, draws much attention to geotechnical engineers while designing economic foundations (Alamgir et al., 2001). In this region, a thick organic soil layer is generally encountered at a depth of 10 to 25 ft. below the existing ground surface and even in deep sub-soils and the organic content ranges from 5 to 70% and even more in some instances (Islam, 2006). The sub-soil property in Khulna region at major layer largely depends on the percentage of organic contents. While, choosing both the shallow and deep ground improvement technique through cement stabilization, the strength-deformation behaviour of cement stabilized soil of this region should be evaluated properly. Das (2005) investigated the strength-deformation properties of inorganic soils of Khulna region by using the varying percentages of cement content from 2.5 to 50% of dry weight of soil. As a follow-up of such research activities, this study concentrates on the strength development of cement stabilized organic soils with period by mixing of 20% cement with the organic soil having wide rage of organic contents varying from 10 to 60% through conducting a series of conventional laboratory tests. Finally, an empirical equation is proposed with some conditions, to determine the strength of cement stabilized organic soils for different organic contents.

MATERIALS AND METHODS

The properties of the constituent materials and the procedures adopted in the laboratory for the preparation of required test specimens of cement stabilized organic soils are presented in the following sections.

Collection of Soil Samples

Inorganic soil sample was collected from KUET campus at depth of 3 to 5 ft. below the existing ground surface, while the organic soil sample was collected from Dakatiabil at a depth of around 10 to 12 ft. below the existing ground surface, which is 3 km away from KUET campus. The collected soil samples were dried up into air and then manually crushed into the powdered form. Dust samples were sieved through number 30 sieve (0.59 mm). Organic content was determined by the standard loss on ignition process (ignition at 500 to 550^{0}C for more than six hours). Other physical properties were also determined by using the conventional laboratory tests. For stabilization purpose, ordinary Portland cement (King Brand) is used as the cementing agent. The properties of the constituent materials are presented in Tables 1 and 2.

Table 1: Physical Properties of Soils Used in this Study

Physical properties	Measured average values	
	Inorganic clay	Organic clay
Natural water content (w)	34.50%	83.00%
Liquid limit (LL)	42.00%	75.00%
Plastic limit (PL)	24.00%	64.00%
Plasticity index (IP)	18.00	5.00
Specific gravity (Gs)	2.71	2.00
Organic contents	4.50%	60.00%

Table 2: Physical Properties of Cementing Agent Used in this Study

Physical properties	Measured average values
Normal consistency	26.00%
Initial setting time	50 minutes
Final setting time	5 hours 45 minutes
Fineness	3.86%
Mortar cube strength, 3 days	1,750 psi
Mortar cube strength, 7 days	2,900 psi

Preparation of Test Specimens

Both the soil samples as stated in Table 1, were mixed with each other at different proportions to prepare the designated test specimen of 10%, 20%, 30%, 40%, 50% and 60% organic contents. With every sample of prepared organic soils powder, designated cement as stated in Table 2, were mixed thoroughly at 20% dry weight of corresponding organic soil samples. Soil and cement mixtures were then mixed thoroughly and uniformly with the water content, equal to the liquid limit of respective soil sample, to prepare a homogeneous soil-cement paste. The paste was then put into the plastic mould very carefully using fingers so that no air void can entrap within the soil samples. The samples were driven out of the mould and the specimens were then wrapped properly by air tight polythene and kept under water for curing of 1, 3, 7, 14 and 28 days. After the completion of curing periods, the specimens were used for the required conventional laboratory tests. The whole process of the preparation of test specimen is shown in a flow-chart in Figure 1.

RESULTS AND DISCUSSIONS

The test results on cement stabilized organic soils obtained from the conventional laboratory tests are described here. The effect of organic content on some geotechnical properties of soil and also the strength development of cement stabilized organic soil containing the varying percentages of organic contents are also discussed.

Effect of Organic Contents on Physical Properties

Physical properties of soils are changed considerably with different organic contents as shown in Table 3. The laboratory tests show that the value of liquid limit and plastic limit has changed from 42 to 75% and 24% to 70%, respectively, for the increase organic contents from 4.5 to 60%. For the change of organic contents in the same range, the value of specific gravity decreases from 2.71 to 2.00. More details about the variation of the values

geotechnical properties of reconstituted organic soils with the percentage of organic contents can be obtained in Islam (2006), Alamgir et al. (2006) and Islam et al. (2006).

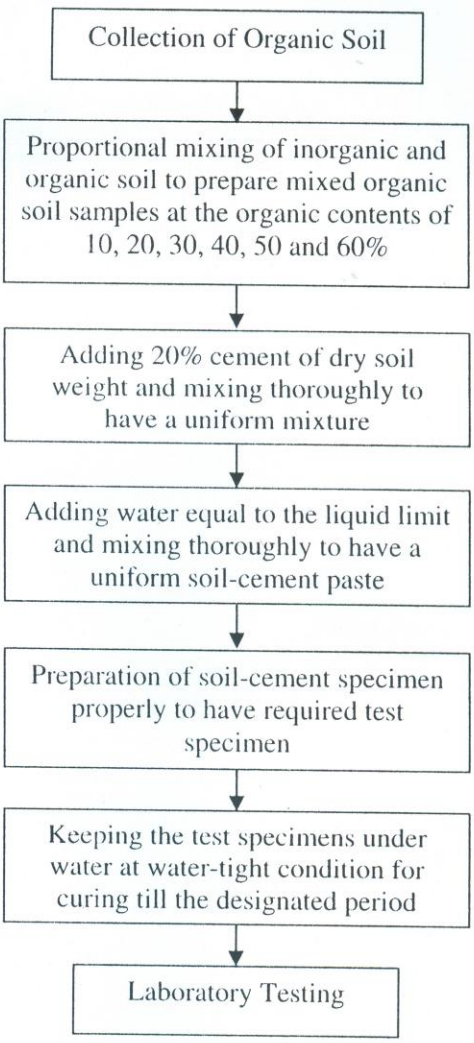

Figure 1: Flow-Chart of Test Specimen Preparation Procedures

Table 3: Physical Properties of Organic Soil Varies with Organic Contents

Organic content (%)	Liquid limit (%)	Plastic limit (%)	Specific gravity (G_s)
4.5	42	24	2.71
10	52	38	2.42
20	58	44	2.34
30	62	46	2.26
40	68	55	2.19
50	70	60	2.12
60	75	70	2.00

Strength-Strain Behaviour of Cement Stabilized Organic Soils

A series of unconfined compressive strength tests were performed on the cement stabilized soil samples having particular cement content (20%) containing different proportions of organic matter varying from 10 to 60%, for the curing period of 1, 3, 7, 14 and 28 days. The pattern of stress-strain are almost similar for all curing periods as shown in Figure 2 for the curing period of 7 and 28 days.

Strength Development with Curing Period

The cementation in soil-cement paste proceeds with curing period as the microstructure is being changed with time as the cement hydrates. The development of strength with curing period is shown in Figure 3 as obtained from unconfined compression test on soil-cement specimens. The result shows that the compressive strength increases significantly as the curing period increases. But the strength does not increase at the same rate in all curing periods. The test results also show that the rate of strength increment with curing significantly depends on the percentage of organic contents exists in the specimen.

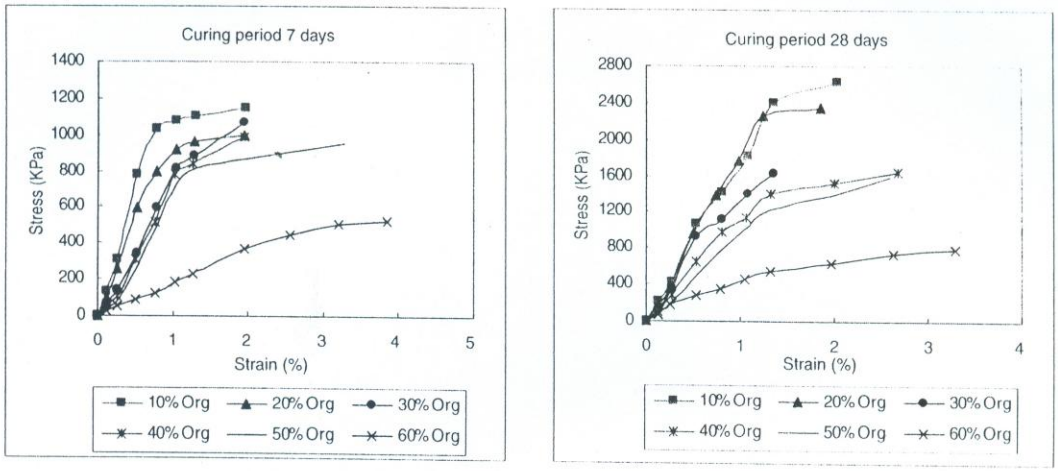

Figure 2: Stress-strain Behaviour of Cement Stabilized Organic Soil

For the soil-cement sample having 10% organic content, strength varies from 688 to 2624 kPa for increase of curing periods from 1 to 28 days, while it varies only 300 to 845 kPa in case of 60% organic contents. The reasons for this variation of strength are the diversity of plasticity index as well as the presence of percentage of organic matter in the soil, which might prevent the strength development.

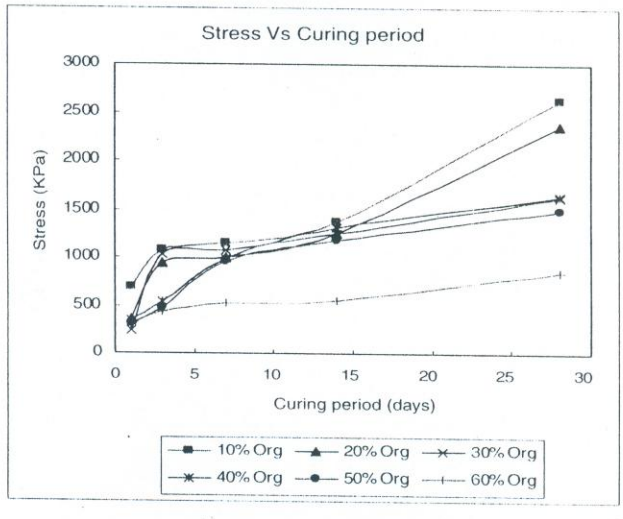

Figure 3: Variation of Strength with Curing Period

Effect of Organic Contents on Strength Development

Franklin et al. (1973) stated that the undrained shear strength is a function of organic content for a natural soil and soil peat mixtures and also the interconnected bonding of soil particles i.e. the cementing bonding. Due to the addition of required percentage of cementing agent in an organic soil specimen, although the strength has increased due to the changes microstructures, but the degree of increment is largely dependent on the percentage of organic contents. As the percentage of organic contents increase, the size of the larger particles mainly partly or fully decomposed organic matters increase which resulting the interconnected particles contracts within

organic matters and cementing agent instead of solid soil particle contacts with the cementing agent.. As the organic matter bears low strength and high compressibility, the strength properties of soil-cement mixture reduced with the increase of organic contents. The behavior has been observed in the test results as presented in Figure 4, which shows the variation of unconfined compressive strength with the increase of organic contents. In this figure, the variation of strength of soil-cement sample is presented for the strength development at 28 days curing period for the mixing of 20% cement having the variation of organic contents from 10 to 60%. The result reveals that the strength development for cement treated organic soils reduced from 2624 to 845 kPa for the increase of organic contents from 10 to 60%.

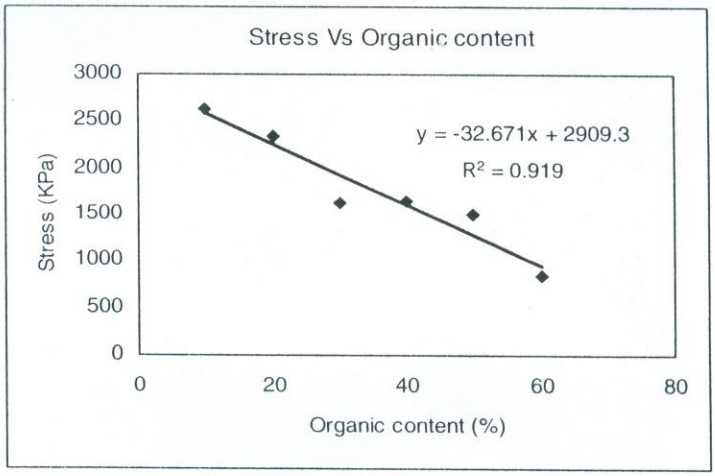

Figure 4: Variation of Compressive Strength with Organic Content

The results presented in Figure 4, can be expressed through an empirical equation as given in Equation 1. This equation can be used to determine the 28 days strength development in the organic soils of Khulna region at the organic contents of 10 to 60% for mixing ordinary Portland cement at 20% of dry soil.

$$q_{ucs} = 2909.3\text{-}32.67\ (O_c),\ \text{where } 10<Oc<60 \qquad (1)$$

Where, q_{ucs} = Unconfined compressive strength of cement stabilized soil in kPa
O_c = Percentage of organic content

CONCLUSIONS

Based on the laboratory investigation and test results of the present study, the following conclusions can be made:

(i) The strength of organic soil can be increased significantly by applying the cement admixtures allowing required curing period.

(ii) The degree of strength development in organic soil decreases with the increase of the percentage of organic content present in the organic soils.

(iii) The rate of strength development with curing period significantly depends on the amount of organic contents present in the soil.

(iv) An empirical relationship can be proposed with some conditions to estimate the amount of strength development for different percentages of organic contents.

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