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Durability and Swelling of Tropical Stabilized Peat Soils

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Abstract: This research describes a study on peat soil stabilisation to improve its physical and engineering properties. It investigates the effect of additives (binder amount 5, 10 and 15% (85% cement, 15% bentonite) and range of sand 5 to 25% on the index properties as well as, durability, plasticity and swelling of tropical peat soils. The amount of additives added to the peat soil sample was investigated in terms of the percentage of the dry soil mass. The results showed that of the additive admixtures altered the engineering properties of tropical peat soils. The soil plastic limit, liquid limit and plastic index were found to decrease with increase of the additive content. Swelling of stabilized peat soils was found decrease with increase additives, however, the curing time. The effect of durability increased resistance of strength for lower content of addition to higher content additives.

Key words: Ordinary portland cement, bentonite, sand, peat

INTRODUCTION

Peat soil is a common soil type found in Malaysia, the moisture content of peat soil is very high, almost 800%. Due to high content of organic matter, peat has been used gradually as plantation soil. However, from the engineering specifications, peat soil is problematic soil which has low shear strength and high compressibility which can cause various engineering problems.

The stabilized peat is a new material that has not been investigated earlier, thus little is known about the mechanisms involved in its stabilization. Similarly, many questions remain to be answered regarding its mechanical behaviour in terms of compressibility, permeability and shear strengt (Habib and Farrell, 2003).

Chemical admixtures or chemical stabilization always involves treatment of the soil with some kind of chemical compound, which when added to the soil, would result a chemical reaction. The chemical reaction modifies or enhances the physical and engineering aspects of a soil, such as, volume stability and strength. In the case of sediment soils addition of inorganic chemical stabilizers like cement and lime has a two fold effect on the soil which is acceleration and promotion of chemical bonding. The chemical bounding depends upon the type of stabilizer employed. Strength of silt clay can improved up to 30 folds (Ahnberg *et al*., 1995).

Peat and organic soil represents the extreme form of soft soil. They are subject to instability such as localized sinking and slip failure and massive primary and long-term settlement when subjected to even moderate load increase. Peat is therefore understandable that constructions and buildings on these types of soils are often avoided whenever possible (Bujang Huat *et al*., 2005).

Hence, engineers have resorted to treating or improving the peat soil properties by modifying the *in situ* soils in order for load to be carried out on top of it as well to promote high workability chemical admixtures stabilization has been used extensively in both shallow and deep stabilization to improve the properties of soil such as strength and deformation behaviour. This method may be employed for surface soil, for subsurface formation, or for both. Surface treatment, common in connection with sub grades or bases for pavement construction, generally consist with sub-grade or bases for pavement construction, generally consists of mechanically mixing the soil with chemical stabilizers in place by a batch process.

Usually, laboratory test including the *in situ* tests identify parameters which are essential for foundation design. If these parameters indicate that the *in situ* soil is not capable of carrying the design load then there are tow alternatives to choose, either the limitation impose by the *in situ* soil properties should be accepted, or use the following techniques enabling the loads to lay on the site (Behzad *et al*., 2008).

MATERIALS AND METHODS

Soil sampling: Started this study on 2008 will be finish end of 2010, peat soil from Klang, Selangor, Malaysia is taken as the sample to be improved by adding different

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Table 1: Properties of *in situ* peat soils

Properties	Values
Bulk density (γ_b)	1.59 Mg m^{-3}
Dry density (γ_d)	0.112 Mg m^{-3}
Moisture content (w)	700-850%
Void ratio (e)	10.99
Fiber content	84.99%
Degree of saturation (Sr)	100
Specific gravity (Gs)	1.343
Classification/Von post	H4
Linear shrinkage	5.58%
Liquid limit	173.75%
Plastic index	57.95%
pH	4.6
Loss on ignition	98.46

percentage of binder and sand, tested with several laboratory tests to determine the most effective performance of improved peat soil.

Peat soil usually contains organic material with normal depth of 0.5 m. Peat is known for its high organic content which could exceed 75%. The organic contents classified as peat are basically of plant whose rate of accumulation is faster than the rate of decay. The content of peat soil differs in terms of locations due to factors such as temperature and degree of humification. Decomposition or humification involves the loss of organic matter either in gas or in solution, the disappearance of physical structure and change in chemical state. Table 1 shows the properties of peat soil.

Experimental design: Aim of this study is to investigate the stabilisation of peat soils using cement, bentonite and sand. The research utilizes different content of binder and sand to stabilise peat soils. The procedure involved in this study is divided into several phases described follows:

- **First stage:** First stage of this study is to determine the plastic limit, liquid limit plastic index values of stabilised peat soils. Three series of soil mixtures are formulated between the different content of binder and sand. The proportion of these soil mixtures represented several of degree of expansion, low to very high
- **Second stage:** Second stage is to determine the potential swelling and durability of stabilised peat soils

The dosage rate is the amount of stabiliser added to the soil. There are two methods of defining the dosage rate: kg of stabiliser m^{-3} or treatable soil and kg of stabiliser m^{-3} treated soil. The former method bases the amount of stabiliser on the volume of soil that is to be replaced and the latter on the other hand bases the amount of stabiliser on the volume of soil after treatment.

Table 2: Admixture design

		Stabiliser (%)			Sand content
Samples	Peat soil (%)	Cement	Bentonite	Binder by volume	By volume (%)
CBS 1A	90	85	15	5	5
CBS 2A	85	85	15	5	10
CBS 3A	80	85	15	5	15
CBS 4A	75	85	15	5	20
CBS 5A	70	85	15	5	25
CBS 1B	85	85	15	10	5
CBS 2B	80	85	15	10	10
CBS 3B	75	85	15	10	15
CBS 4B	70	85	15	10	20
CBS 5B	65	85	15	10	25
CBS 1C	80	85	15	15	5
CBS 2C	75	85	15	15	10
CBS 3C	70	85	15	15	15
CBS 4C	65	85	15	15	20
CBS 5C	60	85	15	15	25

In tandem with the proposed investigation, dosage rate was calculated based on volume of stabiliser cm^{-3} of treatable soil. In order to test the effects of different additives and proportions effectively, it was important that a large dosage be tested. The amount of binder is 5, 10 and 15%. A proportion of cement and bentonite was studied, that is 85:15%, respectively. Moreover, sand was added ranging from 5 to 25% with an increment of 5% from the volume of screened peat soil. Table 2 shows the combination of rate proportion that was used to test for each admixture. Three series of admixtures shown on Table 2, Cement Bentonite Soil (CBS A,CBS B and CBS C), first series is 5% binder from the total volume of dry peat soil, second series 10% binder and third series 15% binder, however the range of sand from 5 to 25% for each series.

RESULTS AND DISCUSSION

Effect of stabiliser addition on liquid, plastic limit and plastic index: The Atterberg consistency limits were determined in accordance with the British Standard Methods-BS 1377: Part 1-4 (1990). The screened peat and stabilised peat were sieved through a 2 mm sieve. Materials that were retained on the sieve were rejected for this test. The tests were carried out on the soils with different proportions of binder and sand.

Addition of binder and sand to peat soil decreased the plastic limit. The reduction of plastic limit was due to hydration of cement which produced cementation between the particles of soils. The results of liquid limit and plastic limit show in Fig. 1 and 2.

The physical conditions of soil are an indication of reheological behaviour. Consistencies are obviously related to the force of attraction between the particles or aggregate of these particles. Different soils have different

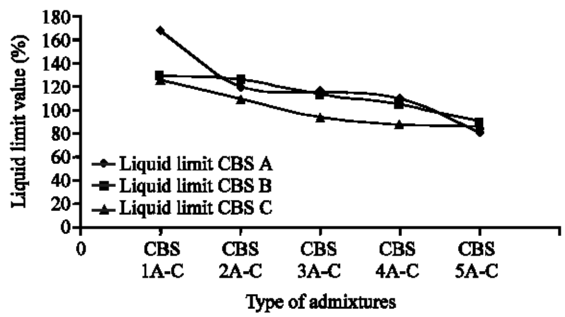

Fig. 1: Variation of liquid limit of peat soil with additives

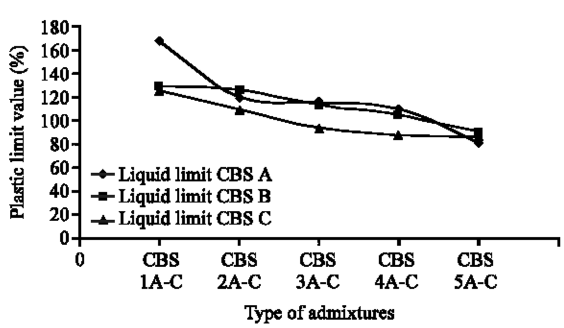

Fig. 2: Variation of plastic limit of peat soil with additives

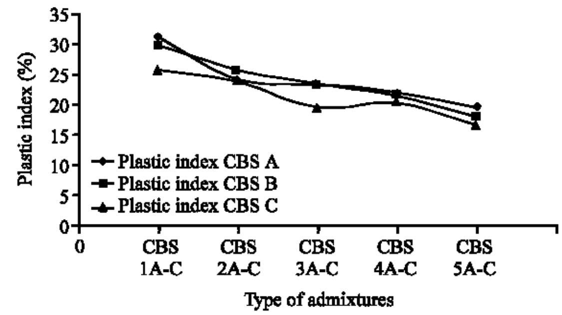

Fig. 3: Variation of PI of peat soil with additives

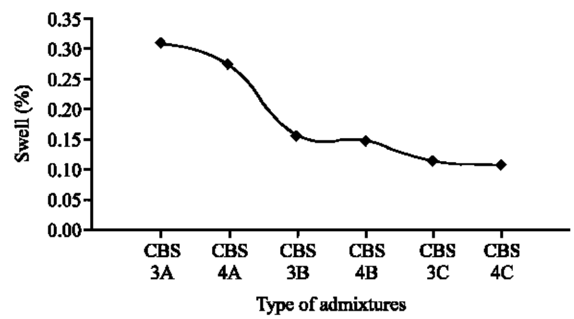

Fig. 4: Potential swell of stabilized peat soil

consistency at different water contents and specifications of these conditions give some information about the type of soil material.

The liquid limit depends only on the fine particles present. The variation in liquid limit of different clays is greater than that of the plastic limit. The influence of exchangeable cations and salt concentration is also greater. Inter-particle force has a more preeminent role in determining the liquid limit (Raymond and Benno, 1975).

The difference between LL and PL was very clear. Figure 3 shows the plastic index of soils with different additives and it indicates the difference between liquid limit and plastic limit. In fact, the differences between the values between the liquid limits and plastic limits may be related to specific surface areas, water absorption characteristic and inter-particles forces.

The plasticity index is the ratio of the difference in water content between the natural or *in situ* water content of a soil and its plastic limit to its plasticity index. British Specifications (BS) specify the maximum plastic index less than 20% for soils to stabilize with cement to form capping layers.

Swelling test: It is well known nowadays that peat soil and the associated swelling pressure on foundations result in considerable damage to structures. Stabilized peat soil is susceptible to swells as moisture content of the soil increases. Upon expansion, the soil exerts an upward pressure on foundations. If this pressure is greater that the foundation pressure, then uplift of differential uplift occurs causing walls, beams and columns to crack. Consequently, reducing the swelling is an important step in designing a construction on stabilized peat soil.

The percentage of swelling after 3 days curing was determined to be decreased by 66%. In this investigation, the proportion of binder varied from 5 to 15%, proportion of sand varied 15 to 20% and proportion of peat soil from 80 to 65%. The swelling of samples was measured during soaking and after compaction. From the indicators that can be used to classify the Swelling Potential (SP) of the soil are plastic index and liquid limit (Chen, 1975, 1988) classified soil with PI>35% as having very high swell potential, 15<PI<35 having medium swell potential and PI <15 having low swell potential. The swell potential is higher for higher plastic index, according to Chen's classification, 25<PI<35 marginal SP and PI>35 high SP.

Figure 4 shows the results of adding additives (binder + sand) to peat soils; (O'Neill and Poormoayed, 1980) classified soils with PI<25 as low SP, PI from 31% for 5% binder to 16.4 % for 15% binder according to (O'Neill and Poormoayed, 1980) the PI<25, which is an indicator that potential swelling is low.

Chen (1983) investigated the relationship between plasticity index and swelling percent under different pressure. Table 3 shows relationship between swelling

Table 3: Relationship of swelling potential to plasticity index

1 psi pressure (%)		6.94 psi pressure (%)	
Swell	Plasticity index	Swell	Plasticity index
0.2	5	0.10	5
0.3	10	0.15	10
0.35	15	0.20	15
1	20	0.30	20
1.3	25	0.40	25
3	30	0.90	30
5	35	1.30	35
7	40	3.0	40

Chen (1983) foundation expensive

Table 4: Classification of soils related to plasticity index

Swelling potential	Plasticity index
Very high	>55
High	20-55
Medium	10-35
Low	0-5

Chen (1983)

potential and plasticity index which can be established as shown in Table 4.

The swelling of the soil in the road pavement (base and sub-base) is undesirable. The decrease in swelling is due to cement materials. Cementation which is the process which normally occurs due to hydration and pozzolanic reaction where it encloses soil particles into a strong matrix which tends to resist internal stresses due to water which causes the swelling and as a result, the swelling would decrease. Figure 4 shows the swell decreasing when the additives increased.

Durability test: A stabilised soil should be durable in which it has ability to retain its integrity and strength under service environmental condition. The conformity to this requirement is more critical when the strength of the stabilised soils is low. The determination of the durability properties of the soils mixtures is a problem since it is difficult to simulate the detrimental action in laboratory, which in reality is produced by weathering in the field. Hence, it is important to examine the effect of immersion in water on the unconfined compressive strength of stabilised soils with binder and sand.

From Fig. 5 it is found that increasing the percentile of binder from 5 to 15% enhances the resistance increased. According BS 1924- (1990) the effect of curing and immersion was examined for selected samples. CBS 2A, CBS 2B and CBS 2C were subjected to three different treatments. The results are shown in Fig. 5, method 1 (5 days moist cured + 2 days immersed), method 2 (7 days moist cured +7days immersed) and method 3 (21 days moist cured +7 days immersed), followed by method 1, method 2 and 3. Overall, the results provide evidence that duration of curing and immersion considerably affects the treated soil with binder and sand. The effect of soaking is

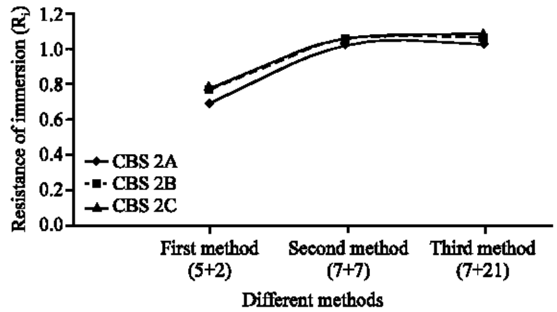

Fig. 5: Effect of curing immersion treatment on the resistance to immersion

dependent on the level of strength of pozzolanic reaction achieved prior to beginning of the period of soaking. Compressive strength subjected moist cured, R_i = resistance to immersion = P_i/Pc.

The results also indicate that increase in curing periods increased the strength of the materials. This increment was mainly due to the pozzolanic reaction which occured after the early strength of cementing reaction which took place.

In general, the unconfined compressive strength of stabilised loss subjected to immersion test, which is R_i<1. Results of resistance of immersion are shown in Fig. 5, about 5% binder for first method (2 days immersion and 5 days moist cured).

Resistances of immersion lower than 1 means the stabilised peat was not durable or the immersion strength was lower than the moist cured strength. Yet for the second and third method the resistance of immersion was almost 1, hence the stabilised peat soil with more curing was more durable. However, for 10 and 15% binder, the resistance of immersion was lower than 1 for the first method, but increased more than 1 for the second and third method. Thus on the whole that duration of curing and immersion, considerably affected the treated peat soil with binder and sand, the effect of soaking was dependent on the level of strength of pozzolanic reaction achieved prior to beginning of the period of soaking. Loses in strength of specimens subjected to immersion is possible caused by absorption of water along immersion.

CONCLUSIONS

Peat and organic soil represents the extreme form of soft soil. They are subject to instability such as localised sinking and slip failure and massive primary and long term settlement when subjected to even moderate load increase. The conventional method constructions on peat are usually carved out after excavation and replacing new material. But this method faces many problems such as, difficultly to find new materials and due to high costs of excavation and transport. The conventional method which is presented in this study improves the engineering and mechanical properties of peat soil. To date there has not been much incentive to try and understand the engineering or mechanical behaviour of this type of soil, although these soils are found in many countries throughout the world. Peat has certain characteristics found from laboratory tests; high compressibility 36%, low shear strength 8.73 kPa. However, acidic materials pH = 4.65.

The findings of stabilised peat soil are as follows:

- The addition of binder and sand to peat soil decreased plastic limit, liquid limit and plastic index by 75, 74 and 70%, respectively. The BS specification specifies the maximum plastic index as less than 20% and that material can be used for road or highway construction
- The swelling potential of peat soils decreased in concomitant with the addition of binder and sand. The swelling of peat soil was almost zero when 15% binder was added
- Increasing the durability indicated improvement of serviceability as resulted in wheel tracking test. The immersion resistance increased for 7 days more than 1 means the strength for materials increased

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