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An attempt to improve plantation road soils using an organic stabilizer

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Abstract: This paper reports the findings of an attempt to improve the strength properties and durability of plantation road soils using a liquid organic stabilizer. Laboratory investigations were done for CBR, and durability in terms of loss of weight in alternate wetting and drying, on five selected soil samples using various proportions of stabilizers. The study suggests that there is an optimum dilution ratio of the stabilizer for the improvement of these soils. Beyond this optimum dilution ratio the strength improvement occurs consistently, though not significant. Statistical analysis of the data obtained from the laboratory tests were also done. Correlation was obtained for CBR value as against the stabilizer dilution ratio.

INTRODUCTION

In constructing the road system within a plantation area, cost and effectiveness would be the main considerations when deciding the type of road designs to use. Normally plantation roads are earth roads as soil is the easiest and cheapest materials available in large quantities that can be used as a construction material. These plantation earth roads are compacted mechanically to increase its load bearing capacity such that it can carry a safe load without undergoing any detrimental deformation. A layer of gravel might also be used to top the road and compacted together with the soil to achieve a further gain in strength. Plantations would seldom use tar or bitumen sealed roads, as the costs are too prohibitive. Besides, the effort and cost needed to alter these roads would be quite high if there were any changes in the plantation setup.

Earth roads are the most basic roads. These roads are relatively cheaper to build while compared to other alternative viable. The plantation earth roads are susceptible to damage due to weather and the passage of heavy vehicles. Generally, the roads are topped with gravel such as limestone or granite to increase the load bearing capacity and life-span of the road.

As Malaysia is a tropical country with a monsoonal climate, the rainfall tends to be particularly heavy. These heavy monsoonal rainfalls would increase the rate of degradation of the plantation roads. During heavy rainfalls and storms, these earth roads are transformed in many cases into masses of mud whereas in dry weather, clouds of dust occurs as vehicles pass by. In certain developing nations, it is estimated that up to 25% of farm produce do not make it to the market due to these poor road conditions (Tang, 1999). This highlights the need for better road materials especially when dealing with earth roads in wet conditions. Soil stabilization especially using chemical/ organic soil stabilizer may be considered one of the viable options to improve the soil conditions of earth roads. However, the techniques suited for a soil are highly sensitive to the basic properties of both soil and the stabilizer. Importantly, improper stabilization method may lead to ineffective exercises.

In Malaysia, various projects dealing with soil stabilization using chemical stabilizer, especially in palm oil plantations have been undertaken in recent years. According to Hitam and Yusof (1998), hardening and stabilizing the road surface by chemical means was carried out at the Palm Oil Research Institute Malaysia (PORIM), Paka Research Station in 1996 and by Federal Land Development Authority (FELDA) in 1994. Both PORIM and FELDA reported to have achieved a better quality all weather roads using organic soil stabilizers. Organic stabilizers were also used in palm oil plantations in Sabah, while the Public Works Department (JKR) used several chemical/ organic stabilizers for road shoulders and unsealed village roads. Though, chemical/organic stabilizers in some of these cases were found to enhance the properties of soil, but for plantation roads the results were not encouraging (Tang, 1999).

In Sarawak, the Sarawak Land Consolidation and Rehabilitation Authority (SALCRA) used an organic soil stabilizer in a pilot project at one of their plantation sites. The organic stabilizer used was a hybrid of Terrazyme. The present study was undertaken as a research interest on the use of this chemical for soil stabilization purposes of plantation roads. The objective of this study was to quantify the effectiveness of this stabilizer when used in soils with regards to strength (stiffness) and durability.

Table 1. Index properties and soil classification.

Sample No.	NMC (%)	% Passing 63 m sieve	% Clay size	Limit test results				Soil Group	Activity of soil
				LL (%)	PL (%)	PI (%)	LS (%)		
1	49	97	64	94	56	38	18	A-7-5	0.59
2	46	66	26	52	35	17	12	A-7-6	0.65
3	33	72	35	52	32	20	10	A-7-6	0.57
4	40	76	56	55	36	19	13	A-7-6	0.34
5	46	84	37	92	47	45	14	A-7-5	1.22

An experimental investigation was carried out in the laboratory. Soil samples were collected from selected locations and they were treated with various proportions of stabilizers. Tests were done for the physical properties, California Bearing Ratio and Durability of both untreated and treated soils were determined. Data obtained from the tests were analyzed to assess the effect of the stabilizer on the soil. Some interesting relations were obtained between stabilizer content and soil stiffness, and also between stabilizer content and durability of soil.

TEST PROGRAMME AND PROCEDURE

Soil and Stabilizer used in Stabilization

Five soil samples were collected from the palm oil plantation project of Taee Research Station owned by SALCRA located along the Kuching Serian Road, Sarawak. The samples are designated as Sample 1 through 5. Routine laboratory tests were done for soil classification and the data are presented in Table 1. Grain size distribution of all the five samples is presented in Figure 1. According to AASHTO soil classification (AASHTO, 1982), samples 1 and 5 were A-7-6 whereas rest three were A-7-5, all being clays. In terms of activity (Table 1), they were soils of normal activity.

The liquid soil stabilizer, with a brand name of *Good Earth Plus*, was provided by SALCRA. In its literature, it was claimed to be of TerraZyme hybride, though no chemical formulation of the product was given. A detailed chemical analysis of the stabilizer was out of the scope of the present study and further details can be obtained from SALCRA (1999).

Based on the classification tests results, the soil samples of Taee Research Station Plantation Zone can be grouped into two broad types. Type A comprises of samples 1 and 5, and the rest of samples fall in Type B. As such, further investigations were done under the heading of these two types of soil namely A and B. According to AASHTO soil classification system, these types of clay soil (A-7-5, A-7-6) are considered to be the worst quality of soil to be used as a subgrade material. In the upper layers of the pavement, the use of finer soils of desired gradation is usually recommended. However, the soils used in the present investigation were much more finer and failed to meet the gradation criteria as mentioned by Kezdi (1979). In these types of soil, water soil relations are prominent and almost every problem related to use of fine soils is due to unfavourable interactions between water and soil. Chemical stabilization, in such cases, may be a viable method of improvement of soil strength where bonding and ionization play an important role to impart cohesive properties and thus strength of the soil. Details of these aspects can be found in Kezdi (1979). The principal objective of chemical stabilization is that the soil should maintain its characteristics regardless of the moisture in its environment.

Test Scheme

Modified Proctor compaction tests were done on the untreated soil samples to determine laboratory maximum dry density and optimum moisture content. The strength test was done on the samples compacted near to laboratory maximum dry density with optimum moisture contents. Similarly, for durability tests, initially the samples were also prepared at that density and moisture content. Stiffness was considered as a measure of strength in this study. As such CBR tests were done on the prepared samples using the procedure outlined by BS1370: 1990. The durability test was aimed at testing the reaction of the stabilized soil to the effects of repeated wetting and drying. These tests were done for both types of soils using various concentration (percentage) of liquid stabilizer in water used in compacting the soils. Reproducibility of the test results was examined by repeating the tests twice. The testing scheme is presented in Table 2.

Laboratory compaction test of the samples was carried out, as per BS1377: Part 4: 1990, in order to obtain the indices like dry density and optimum moisture content. These indices are used as reference values in estimating the density in any earthworks. The test results gave a maximum dry density of 18.6 and 19.3 kN/m^3 respectively for soils A and B. The corresponding optimum moisture contents were 31% and 25%.

CBR Test

The laboratory CBR tests were carried out on remoulded soil samples of both types of soil (A and B) following BS1377: 1990. Samples were prepared by using a standard compactive effort with a 4.5 kg hammer at 62 blows per layer with each mould having 5 layers of soil. The moisture content was maintained for each layer at optimum moisture content obtained from the compaction test. Once the compaction of the soil had been completed in the CBR mould, the collar of the mould was removed and the excess soil was trimmed off to be flush with the top of the mould using a straightedge. The sample was then cured in air for 3 days. After that the soaking process was conducted by placing the mould with proper surcharge within a water tank. The mould was removed from the soaking tank after 3 days and the water allowed to drain from the soaked soil for 15 minutes. The sample for CBR test was thus prepared and CBR value was obtained at soaked condition. For each types (A and B) of soil, four such samples were prepared using various proportions of stabilizer and tested for CBR.

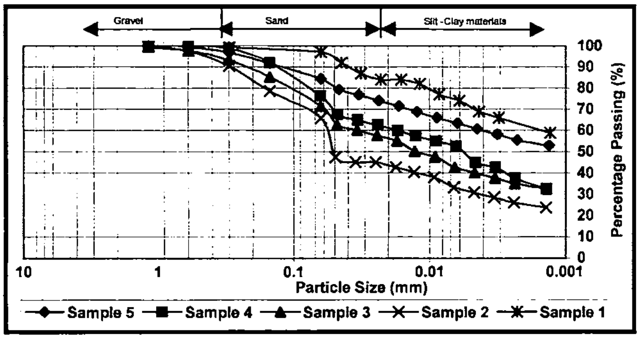

Figure 1. Grain size distribution of the soils used in the stabilization.

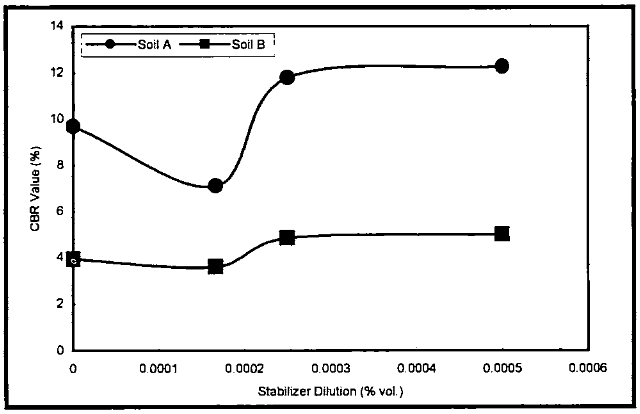

Figure 2. CBR value against stabilizer dilution.

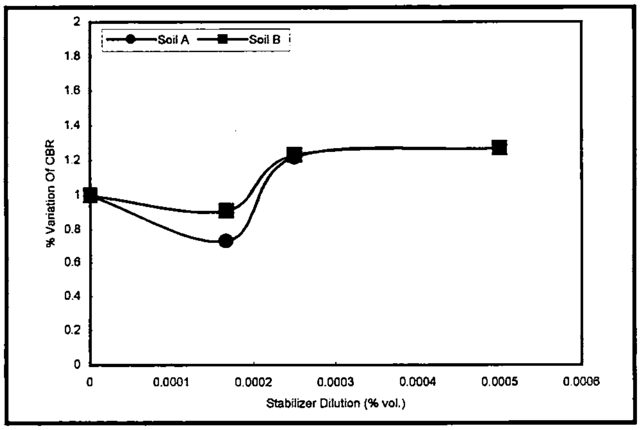

Figure 3. Variation of CBR value against concentration of stabilizer.

Durability Test

Durability test was done according to method suggested by Kezdi (1979). As mentioned before, this test was aimed at investigating the reaction of the stabilized soil to the effect of repeated wetting and drying.

Similar to that of the CBR test, samples were prepared by compacting the soils in a compaction mould to the desired density and with known moisture content. The samples were then extracted from the compaction mould and placed in wet surroundings for curing. After 24 hours, the soil cylinders were submerged in water and then placed into an oven at 105°C for drying. Allowing further 24 hours for drying, the weight of the soil cylinder was taken. Then a wire brush was used to brush across the sample. The loss of weight of soil sample due to brushing was measured. The above steps represent a single cycle and a complete durability test requires 12 cycles. For each soil sample and each of the tests, two soil cylinders were required. Thus each soil sample in this study required eight cylinders as the samples were tested for untreated water (no stabilizer used) and treated water having three different dilutions (1:6,000, 1:4,000 and 1:6,000). A graph was then plotted showing the weight loss in percentage of the original weight versus the number of cycles to determine the durability.

EFFECTS OF STABILIZER CONCENTRATION ON CBR VALUE

The CBR values obtained from the tests for both treated and untreated soil samples are presented in Figure 2. The variation of CBR value of the treated soil as compared to that of untreated soil for different stabilizer dilution ratios is presented in Figure 3.

An interesting observation was that at a low concentration of stabilizer (1:6,000), the CBR value was found to be lower compared to that of untreated soil. The reduction in CBR value was significant for a more plastic soil, like Soil Type A (Figs. 2 and 3). This might be because of the re-orientation of the clayey particles, thus affecting the soil structure with the presence of newly included organic stabilizer. There could be a formation of dispersed structure thus reducing the shear strength.

At higher concentrations, however, the CBR value was found to increase. Thus there was a minimum value of stabilizer dilution (1:4,000) beyond which the CBR value was found to increase significantly (Fig. 2), further to that the increase rate was not prominent.

Statistical analysis of the very limited number data yielded the following relationship, with a strong coefficient of correlation (r^2) of 0.99, between stabilizer dilution and percent increase of CBR value beyond the optimum value of stabilizer dilution.

$$y = 1.18 + 0.018x \qquad (1)$$

where, y denotes the percent increase in CBR value and x the stabilizer dilution in 10^{-4}.

EFFECTS OF STABILIZER CONCENTRATION ON LOSS OF WEIGHT

The average loss of weight due the alternate wetting and drying of the soil is presented in Table 2. The results are also plotted in Figures 4 and 5 to show the absolute variation and variation ratio of weight loss as compared to that of untreated soil.

The results were found to indicate a lower weight loss for stabilized soil samples as compared to the untreated soils (Figs. 4, 5 and Table 2). The weight loss was relatively higher in case of more plastic soils. However, no specific trend was observed for this weight loss phenomenon.

The phenomenon concerning the effects of the organic stabilizer on the durability of the soil sample may be explained as follows. Firstly, organic or chemical stabilizer like *Good Earth Plus* might only change the water soil relationship but did not by itself act as a bonding agent in the soil matrix. Secondly, the study of soil structure of compacted soil both before and after using the stabilizer may warrant a reasonable explanation for this no trend of strength improvement. Most importantly, as it was observed that both the soils even could not withstand the second cycle of wetting thus behaving like a collapsible soil.

CONCLUSIONS

Of the many aspects of stabilized earth road construction, only the chemical treatment of the soil using a liquid chemical was studied in this investigation. Depending on the limited amount of data available from this study, the following conclusions can be drawn:

i) There is an optimum dilution ratio of stabilizer for the improvement of soil CBR. The CBR increase is in the order of approximately 25% and may be expressed by the relationship given by equation (1).
ii) The results of durability test for stabilized soil are not encouraging. Though some improvement was observed for the first cycle of wetting and drying, the subsequent cycles yielded the collapse of the soil structure.
iii) The organic soil stabilizer may not be effective for all types of soil. As such, before using these types of stabilizer in a construction, their effectiveness should be studied either by pilot field tests or by laboratory observations.

There is, however, further scope of study for using this liquid stabilizer to modify the bonding properties of soils so as to use them as an upper layer of earthen roads.

Table 2. Test results for CBR and average weight loss (durability).

Test	Dilution Ratio (% volume)	Soil A Variation	Soil A Variation Ratio	Soil B Variation	Soil B Variation Ratio
CBR	0	9.7	1.00	3.9	1.00
	1:6,000	7.1	0.73	3.6	0.91
	1:4,000	11.8	1.22	4.9	1.23
	1:2,000	12.2	1.27	5.0	1.27
Durability (Average weight loss)	0	0.16	1.00	0.10	1.00
	1:6,000	0.10	0.625	0.06	0.60
	1:4,000	0.10	0.625	0.01	0.10
	1:2,000	0.12	0.75	0.02	0.20

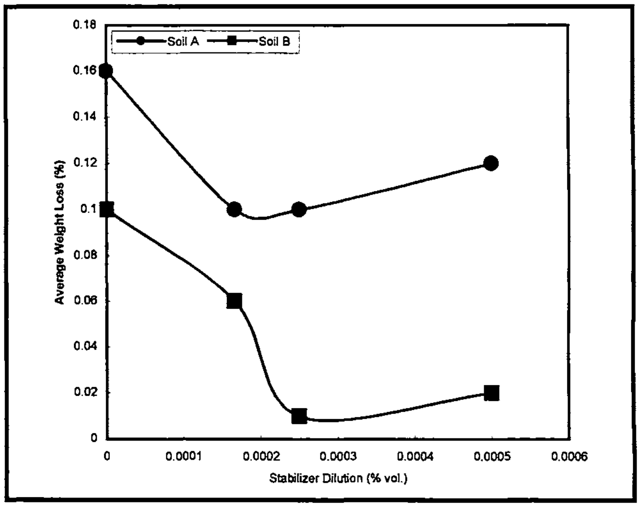

Figure 4. Average weight loss against stabilizer dilution.

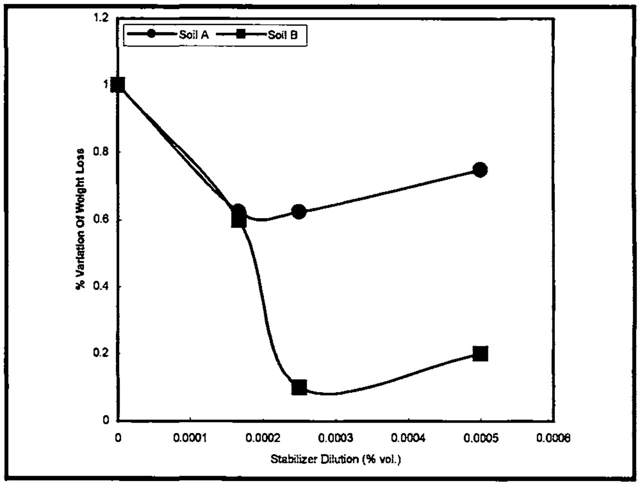

Figure 5. Percent weight loss ratio against stabilizer dilution.

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