SOIL STABILIZATION USING CHEMICAL ADDITIVE

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ABSTRACT

Subgrade is a base layer that is crucial in constructing road that act as a medium in order to cater all the load from the traffic and the load of the road itself. The thickness of the constructing road, stability, strength and the cost of road construction eventually will depend on the strength of subgrade. In other point of view, the soil subgrade will also influence the life expectancy of the road. Soil stabilization is a method to cover the weakness of soil. In this study, soil sample is taken at Kompleks Sawit Sri Meranti, Lepar. The objective of the research is to determine the soil characteristic of untreated soil used in this study, to evaluate the existing strength of treated soil with bi-sulphate at site and to determine the strength of soil when freshly treated with bi-sulphate. Chemical additives using bi-sulphate is another option of soil stabilization that is to study the effect of the usage of these chemical to clay type soil on subgrade layer. The study was conducted by adding different quantity of chemical which is 3, 9 and 15 %. Soil sample was cured for 7, 14 and 28 days for unconfined compression test (UCT). The soil characteristics was defined by having plastic index of 28.69 %, specific gravity value of 2.51, optimum moisture content of 30 % and maximum dry density of 1.37 g/cm3. The test conducted was California Bearing Ratio (CBR) and unconfined compression test which was conducted to determine the soil bearing capacity and strength of soil. The maximum strength for existing treated soil with bi-sulphate at site was 1178.83 kN/m^2 while for untreated sample was 612.52 kN/m^2. When soil was added with 3 % of bi-sulphate, maximum strength of each curing days were 725.68 kN/m^2, 742.59 kN/m^2 and 800.92 kN/m^2 respectively. For 9 % of bi-sulphate added, the soil strength were 893.66 kN/m^2, 968.86 kN/m^2 and 993.13 kN/m^2 respectively for each curing days. Lastly, when 15 % of bi-sulphate added, the soil strength were 812.49 kN/m^2, 867.10 kN/m^2 and 905.10 kN/m^2 respectively. While for CBR when 3, 9 and 15 % of bi-sulphate added were 7.81, 8.18 and 8.22 respectively. For CBR value for untreated and existing treated soil with bi-sulphate at site are 4.68 and 8.4 respectively. Based on the result, it shows that bi-sulphate was capable in increasing the strength of soil. The maximum soil strength was gained when the soil is mixed at 9% with the chemical. The existing strength of treated soil with bi-sulphate at site shows that it has higher strength compared to freshly treated soil.

ABSTRAK

Lapisan subgred adalah lapisan yang penting dalam pembinaan jalan raya yang bertindak sebagai medium untuk menanggung semua beban daripada lalu lintas dan beban jalan itu sendiri. Ketebalan jalan raya, kestabilan, kekuatan dan kos pembinaan jalan raya bergantung kepada kekuatan lapisan subgred. Selain itu, subgred tanah juga akan mempengaruhi jangka hayat jalan. Penstabilan tanah adalah kaedah yang dilakukan untuk menutup kelemahan tanah.Sample tanah diperolehi dari Kompleks Sawit Sri Meranti, Lepar. Objektif kajian ini adalah untuk menentukan ciri-ciri tanah tanah yang tidak dirawat yang digunakan dalam kajian ini, untuk menilai kekuatan tanah yang telah dirawat dengan tanah bi-sulfat di kawasan kajian dan untuk menentukan kekuatan tanah yang baru apabila dirawat dengan bi-sulphate. Bahan penambah kimia yang digunakan ialah bi-sulphate merupakan satu bahan penstabil tanah untuk mengkaji kesan penggunaan bahan kimia untuk mengkaji kesan terhadap lapisan subgred tanah liat. Sample kajian dipelbagaikan dengan penambahan peratusan agen penstabil iaitu 3, 9 dan 15 %. Sample tanah dirawat selama 7, 14 dan 28 hari untuk ujian tekanan. Sifat tanah dikenalpasti dengan mempunyai nilai plastik index 28.69 %, nilai graviti tertentu 2.51, kandungan kelembapan optimum sebanyak 30 % dan ketumpatan kering maksimum sebanyak 1.37 g/cm3. Ujian yang dijalankan ialah Ujian Nisbah Galas California (CBR) dan ujian tekanan (UCT) yang dijalankan untuk menentukan keupayaan galas tanah dan kekuatan tanah. Kekuatan maksimum bagi tanah dirawat sedia ada dengan bi- sulfat di tapak adalah 1178.83 kN/m^2 manakala bagi sampel yang tidak dirawat adalah 612.52 kN/m^2. Apabila tanah ditambah dengan 3 % bi-sulfat, kekuatan tanah ialah 725.68 kN/m^2, 742.59 kN/m^2 and 800.92 kN/m^2 . Untuk penambahan 9 % bi-sulfat, kekuatan tanah ialah 893.66 kN/m^2, 968.86 kN/m^2 and 993.13 kN/m^2 pada setiap hari tanah dirawat. Penambahan terakhir iaitu 15 % penambahan bi-sulpfat, kekuatan tanah ialah masing-masing 812.49 kN/m^2, 867.10 kN/m^2 and 905.10 kN/m^2 . Sementara untuk nilai CBR pada 3, 9 dan 15 % penambahan bi-sulfat ialah 7.81, 8.18 dan 8.22. Untuk nilai CBR untuk tanah tidak dirawat dan tanah yang telah dirawat di tapak ialah 4.68 dan 8.4. Berdasarkan keputusan kajian, ia menunjukkan bahawa bi-sulphate mampu meningkatkan kekuatan tanah. Kekuatan tanah maksimum diperolehi apabila tanah dicampur dengan bi-sulphate pada kuantiti 9%. Kekuatan tanah yang telah dirawat di kawasan lapangan menunjukkan bahawa kekuatan tanah adalah lebih tinggi berbanding dengan tanah yang baru dirawat.

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LIST OF ABBREVIATIONS

BSCS	British Soil Classification System
CBR	California Bearing Ratio
FFB	Fresh Fruit Bunch
PVC	Poly Vinyl Chloride
PVD	Preloading Vertical Drain
UCT	Unconfined Compression Test

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Good road network system provide accessibility to people to travel . In the earlier days, roads is used for transportation of earth resources such as iron ore from site to the port. From the point of view, road are the main pulse for a nation economic survival.

In Malaysia, it can be clearly seen that the modernization of the country started by construction of road network system that connecting the whole country. The variety function of road such as transporting people , deliver goods helps to provide a better economic for the country

Unfortunately, not all area is covered with a proper conventional road by means paved roads. It is because due to high cost of proper paved roads to built in plantation and rural area. Moreover, there will be problem if paved road is constructed in the area as the roads tends to be damaged as heavy vehicles with fully loaded will pass through each day.

Unpaved roads is recently connecting the main road to access plantation or rural area. Unpaved roads is exposed to the cause of it to be damaged such as water. The roads tends to deform when loading is apply as the soil contain too much water.

1.2 PROBLEM STATEMENT

The access to the plantation area usually constructed using earth roads. Heavy vehicles will passes through the road in order to transport the goods. The common behavior of unpaved road is pore water pressure, lateral movement, settlement and total stress. Meanwhile, the poor unpaved roads causes the road to be damaged because the soil cannot cater the load of the vehicle. Besides, the road is exposed to water as the road is not covered. The soil will absorb water thus decrease the strength of the unpaved road. The main key to solve this problem is the cost of construction and something that will not disturbed the soil of the plantation area. Soil stabilization is most likely to be suitable to overcome this problem.

Soil stabilization often involving using material that is cement , lime, fly ash . This type of material is easy to apply and low in cost besides it is suitable to change the physical many type of soil . To treat sandy soil, it often required material that has glue properties to bind the soil together , for example cement and asphalt emulsion. For fine grained soil, the required material has the properties to decrease the plasticity index in order to increase the strength of soil.

1.3 OBJECTIVE

The main concern of this study is to provide eco-friendly earth road besides uses less cost compared to conventional road construction in Malaysia. The objectives of the study are:-

1. To determine the soil characteristic of untreated soil used in this study.
2. To evaluate the existing strength of treated soil with bi-sulphate at site.
3. To determine the strength of soil when freshly treated with bi-sulphate .

1.4 SCOPE OF STUDY

The main point of this study is to investigate the effect of bi-sulphates on subgrade soil that has problem with its poor condition and performance. bi-sulphates (liquid) is chosen to be stabilizer for the subgrade soil . The sample of subgrade soil is taken at Kompleks Sawit Seri Meranti, Lepar, Kuantan with coordinate of 3°37'19.1"N 103°08'14.1"E. The scope of this study cover the study previous research to get standardization of the laboratory procedure for preparing mixtures using bi-sulphates besides reviewing procedure for mixture of non-traditional stabilizer. In addition, to identify the engineering properties of soil by conducting following test: specific gravity, Atterberg limit, moisture-density relationship by standard Proctor test. Last but not least to determine the changes in soil strength using Unconfined Compression Test (UCT) and California Bearing Ratio (CBR) when different amount of bi-sulphates is used.

At first, the soil is oven dried before the required test to determine the properties of soil started. Then, the soil sample is prepared at the optimum water content in order to standardize the water content in soil so that the changes in strength of soil when different content of the bi-sulphates used can be easily identify.

CHAPTER 2

LITERATURE REVIEW

2.1 UNPAVED ROAD

Unpaved road are roads that is not constructed using tarmac or concrete surface. It is the top surface of a soil which known as subgrade to the highway engineer. Usually, unpaved roads act as a path for vehicle to pass through in rural area or plantation area.

Unpaved road naturally consist of different characteristic of soil depends on place of the roads. It can be sandy, clayey, rocky which can be affected if there is present of water. The roads will be deformed if vehicle pass through the road when they are wet.

Unlike to paved roads which has gradient to allow water to flow from the road to the drain which located besides the roads, unpaved roads depends on its natural condition where water will flow from high to low. Sometimes, the water will gather in potholes and in worst scenario, if heavy rain strikes, the road may be impassable for vehicles even with off-road vehicle.

2.2 GRAVEL ROAD

Gravel roads is a type of unpaved roads. The roads is resurface with gravel to cover the damage of the dirt road. Gravel road is easy to construct and cheap compared to roads that is constructed using asphalts.

Recent usage of gravel roads especially during wet periods leads the road to rut. Driving on a gravel roads is not comfortable as on paved roads as the surface is not smooth. Besides. The shape of the gravel also contribute to this problem.

2.3 TYPE OF PAVEMENT FAILURE

The roads pavement has a lifespan that is rely on several factors which is water drainage system, environment, the initial design, loading of vehicle and the maintenance that has been done to the pavement to make it last. By identifying the type of pavement failure , it can help to choose the correct method in order to do repairing job.

For unpaved and paved roads , there are several common pavement damage as the soil is not design to withstand heavy vehicle loads and the natural causes.

2.3.1 Rutting

Rutting is one of the damage to the pavement. It causes the pavement to settle within the wheel tracks of vehicle. The main cause of this problem is insufficient soil bearing capacities in that area. This type of failure usually can be seen near the traffic light where extra force is exerted to the front wheel of a vehicle as brake is apply thus imposing extra load to the road. Figure 2.1 shows the rutting of unpaved roads.

Figure 2.1 Rutting of pavement

2.3.2 Potholes

The cause of this road damage is pavement failure. As a result, the asphalt road will exposed its base aggregate. Potholes caused by thin layer of asphalt and water penetration into soil. If potholes is not repaired, the road will be further damaged as the soil is let to stor water. The potholes can be wider and deeper .This will danger the road user especially in the night where the potholes is barely visible.

Potholes should be repair with a method where the road is cut square around the affected area , excavated and new fresh asphalt is laid. Figure 2.2 shows several potholes on unpaved roads at it is filled with water.

Figure 2.2 Potholes on road pavement.

2.4 SOIL CLASSIFICATION

Every soil has different particles shapes and sizes. By drying the soil, the mass of each size range is determine in order to classify the relative proportions. Three categories of soil can be separated which is cohesive, cohesionless and organic soil. For cohesive soil, the soil particle is very small and tend to stack together. While for cohensionless soil, the soil consist large soil particle and it does not stick with each other (Liu and Evett. 2004). On the other part is organic soil that is unsuitable for structure to be constructed above this type of soil because it behave spongy, crumble and compressible. Generally, particle size of soil can be identified according to the equivalent particle diameter (Head, 1992) .Table 2.1 shows the particle size according to their respective type.

Table 2.1 : Classification Of Soil (Newman *et al.* 2005)

Type of Soil	Particle size
Gravel	60 mm to 2 mm
Sand	2 rnm to 0.06 mm
Silt	0.06 mm to 0.002 mm
Clay	smaller than 0.002 mm
Fines	pass a 63 pm sieve
Clay Fraction	smaller than 2pm

2.5 CLAY SOIL

Soft soil is a type of soil that is low in bearing capacity. It can hold more water compared to the other type soil. It has low permeability of water as soil particle is very near apart. Clay soil is generally a type of soft soil.

2.5.1 Characteristic of Clay Soil

The basic shape of clayey type of soil is flat and plate-like or elongated and sizes less than 0.002mm. Clay soil properties behaves as plastic and cohesive between the particle. The particle of the clay soil tends to change its shape when it is compressed or moulded (Whitlow, 1995).

The clay soil behaves differently compared to granular soil based on its engineering properties. The common cause that makes this type of soil decrease in shear strength is by the present of water. The clay soil can expand when wet and shrink when dry besides the soil can be compress and can be plastic. With its low permeability, removing water will takes time when it is compressed (Whitlow, 1995). By means, if a structure is not loaded above this type of soil, the volume decrease and settlement will not occur.

2.5.2 Problem of Clay Soil

One of the problem of cohesive soil is it will have a large amount of settlement if load is apply to the soil. When load is apply, the soil particle will compress which causes water and air void in the soil to leave causing the soil to settle. In addition, this type of soil is low in shear strength and bearing capacity.

2.6 SOIL IMPROVEMENT

In construction. Soil is one of the problem rise during construction phase. Soil that do not pass the required specification will cause the construction to be failed .Poor type of soil such as clay having problem in holding heavy load as it will have large settlement .Clayey soil exhibit plastic when water is absorb and clay soil is able to store water. Engineer has to overcome this problem by improving the soil to follow the specification required. Soil consolidation and soil stabilization is the method that can be done in improving the soil.

2.7 SOIL STABILIZATION

Soil bearing capacities of sub soil can be improve by soil stabilization. Soil stabilization involve myriad method in modifying properties of soil to increase its strength and durability. Modification process involves mechanical and additive process in order to achieve specification that is required. This method is mostly applied on road construction and airfield pavement beside it utilize the available material such as waste material thus reducing the cost of project. The type of modification used is different based on type of soil and the purpose of the construction.

Two types of method in soil stabilization :

I. Mechanical stabilization
II. Additive stabilization

2.7.1 Mechanical Stabilization

Mechanical stabilization method refer to the act that cause the particle of soil to be closely apart by removing air void and water in soil. This will ensure less settlement in the future. Adding granular material such as sand and gravel is also one of the mechanical stabilization that emphasizes on drainage of soil in allowing water to flow out of the soil. Others type of mechanical is vibration by vibroflotation, soil replacement method, compaction, prefabricated vertical drain (PVD).

2.7.2 Soil Replacement Method

Soil replacement method is one of the simplest and uncomplicated method in soil stabilization. In this method, the unstable soil including contaminated or organic soils is remove from the site and it is replace with other suitable soil. This method is applicable only when the ground water table is below the soil that is removed.

2.7.3 Compaction

Compaction is a process where the load or vibration is apply to the soil in order to make the soil particle closely apart. The air void is removed thus make the soil to be denser. Adding water help the soil to be compacted easily but excessive water will cause the strength of soil to be reduce. So, the optimum moisture content and maximum dry density must be obtain from the laboratory compaction test.

On field , the degree of compaction is determined by using density such as sand cone method. Other methods that is used are rubber balloon test, drive cylinder method. At site, moisture content is determine by speedy moisture tester (Nurly Gofar and Khairul Anuar Kassim, 2005).

2.7.4 Vibroflotation

The compaction of granular soil is known as vibroflotation that uses vibrating probe that can inserted into soil in depth up to 100 feet (Stapelfeldt, 2006) . A hydraulic or electric powered probe that consist of water jets and vibrator mechanism is drilled in soil. This process is also known as vibrocompaction. The boring hole is then backfilled with compacted granular soil that act as stone column. This process is the combination of vibro replacement and vibroflotation

The vibroflotation process allows the soil particle to be rearrange in order where the soil particle will fill up the void thus making it denser. Figure 2.3 shows how the vibroflotation works. At first the soil particle in floating condition and the particle rearrange after vibration is apply thus make in dense.

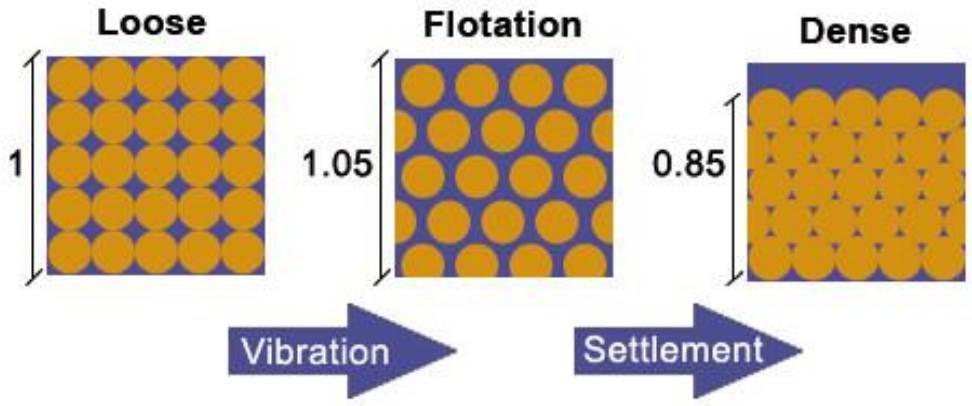

Figure 2.3 Principles of vibroflotation

2.7.5 Preloading And Vertical Drain

Preloading is a method that can used to densify soil. It used on poor silty clay soil, organic material, sanitary landfill that is perfectly suitable to be stabilized by preloading. This method can be used for large scale of construction such as road construction , building and others.

Load is place on top of soil by embankment. The soil is compressed by the load which forces the water out from the soil. Piezometers and settlement plates is provided in order to monitor the consolidation process. Preloading method alone will takes longer times for the soil to settle. To shorten time taken, vertical drain is provided to reduce the time for soil to settle.

There are two types of vertical drains that can be used that is cylindrical sand drains and wick (prefabricated vertical drains).The function of vertical drain is to allow water from the squeezed soil to flow. Cylindrical sand drains consist of vertical sand drains or piles. Figure 2.4 shows how the preloading and vertical drains is functioning..

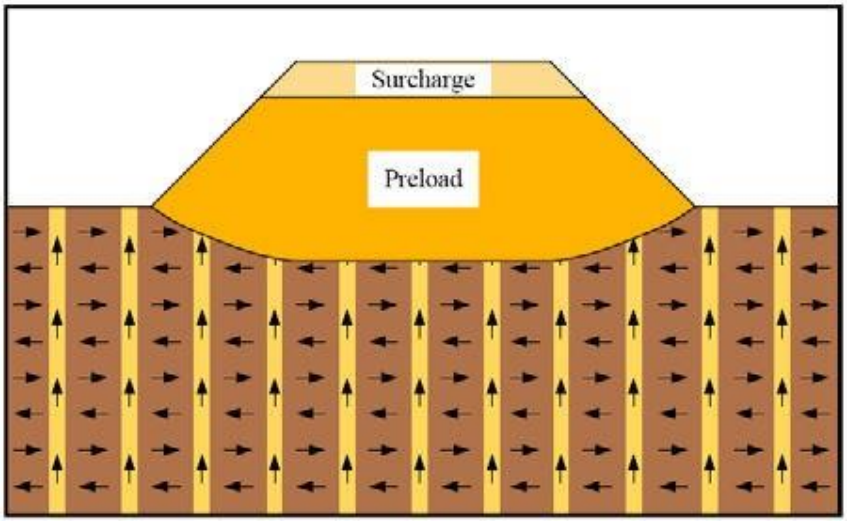

Figure 2.4: Preloading with vertical drains (Stapelfeldt, 2006)

Wick (Prefabricated vertical Drain) is made of hollow lance that is threaded with geotextile filter. The hollow lance then will drive through the soil layer. The strip drains size is normally 100 mm wide and 2 to 6 mm thick.

2.7.6 Additive Stabilization

Additive stabilization is a manufactured product or waste product that is added to soil that can modify the characteristic of soil such as plasticity, workability and strength.

Proper amount of additive is added to the soil to obtain the optimum result. Fly ash, bottom ash, cement and lime are the example of material that is mixed with soil. There are also non traditional material such as polymer based chemical that is mixed with soil. The type and quantity of additive used is determine by the soil classification and the required strength for the soil. Additive has been use widely to improve durability and strength. The spreading and compaction is done conventionally after the soil has been mixed with soil (McCarthy, 2005)

2.7.6.1 Lime Stabilization

Addition of lime in fine grained soil cause the soil to decreased its plasticity and volume change characteristic and improved in workability. The performance of lime stabilized soil depends on many variable. Soil type, quantity and type of lime used, and the crucial part is curing condition (time, temperature and moisture).

There are two effect of lime stabilization that is short term and long term categories. For long term categories, when the quantity of lime is sufficiently added to soil, it will produce a long term strength through pozzolanic reaction. Chemical reaction involved that is cementation and carbonation.

Long term effect

1. Improve shear, tensile and unconfined compressive strength.
2. Reduce shrinkage and gain stability
3. Improve in California Bearing Ratio (CBR)

For short term, when the lime is added with soil, the reaction that occur is that when there is presence of water in soil, hydration and flocculation occur (Newman *et al*. 2005).The effect of addition of lime is soil moisture content will be decrease, optimum moisture content, bearing capacity and plastic limit will increase.

There are many types of lime used for soil stabilization. However, high calcium lime, monohydrated dolomitic lime, dolomitic lime are the most frequently used for stabilization process.

Hydrated lime is most frequently used compared to quicklime as it is less caustic. But the quicklime usage is increasing in these recent years with slurry type application. Hydrated lime content will be decrease for the design lime content if quicklime is used.

2.7.6.2 Soil Stabilization using cement

Cement stabilization is a process where pulverized soil is mixed with Portland Cement and the mixed is compacted to achieve its strength. The act of mixing soil and cement is called soil-cement. During compaction process, some amount of cement is added to fill the void space. Then, water is added in the compaction causes reaction occur between water and cement. Hardening of cement causes bearing capacity and shear strength of soil will improve. The suitable soil for this stabilization is granular type of

soil. Effectiveness of this stabilization will improve when the highest compaction at optimum moisture content of soil (Lambe, 1962 in Bell, 1975).

Literally, there three types of soil-cement mixture which is plastic soil-cement - Contain hardened mixture of soil and cement. It act similar to plastering mortar where enough water to give consistency at the time of placing. The function of this mixture as temporary pavement which is used to pave ditches, slopes or other that related to erosion.

The second mixture is plastic soil-cement - Contain hardened mixture of soil and cement. It act similar to plastering mortar where enough water to give consistency at the time of placing. The function of this mixture as temporary pavement which is used to pave ditches, slopes or other that related to erosion.

Next is cement modified soil. It is a mixture of cement and soil that is unhardened or semi hardened. The physical properties and improvement of soil changes depends on the quantity of Portland cement added. Plasticity and capacity of holding water of soil is reduced when cement is added.

Lastly compacted soil-cement - This mixture of compacted soil and calculated amount of Portland cement added and water to achieved high density. As a result, rigid slab produced that have moderate compressive strength besides it can resist natural weather that is wet, dry, freeze and thaw.

The advantage of addition of cement in soil stabilization is that cement is available widely and in ready stock. The cost is of cement is cheap and the cement is easily transported. The soil cement mixture can withstand different type of weather and strong as the cement will wrap the granular soil particle .In addition, swelling characteristic of soil is reduces.

The disadvantages of cement stabilization is the mixture of soil cement can crack that can reduce its shear strength. It require extra labor as the process need to be mix and compacted evenly. Moreover, sufficient water must be supplied for hydration of cement and make the mixture workable.