Investigation of Stabilised Batu Pahat Soft Soil Pertaining on its CBR and Permeability Properties for Road Construction

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Abstract. Soil stabilization by adding materials such as cement, lime and bitumen is one of the effective methods for improving the geotechnical properties of soils [11] Nano-particle is one of the newest additives and many studies about using nano-particle in soil improvement has been done but it was given less attention when soft clay soils stabilization is concerned. To evaluate the strength characteristics of stabilized Batu Pahat soft clay, laboratory investigation on early strength gained by the stabilized soil must be conducted to formulate a suitable and economical mix design [10]. To achieve such purpose, the study examined the effect of Nano-Clay on the California Bearing Ratio and the Permeability of soft clay. The results gained shows that the Nano-Clay is able to increase the strength of the soft clay [9]. The California Bearing Ratio of the soil is increase significantly where the results for the highest percentage of admixture is 14.4% while the permeability of the soil decreases significantly with increasing Nano-Clay whereby the results of the highest percentage of admixture is 2.0187x10⁻¹¹ m/s.

After doing this research, it is proven that Nano-clay can contribute towards better soil stabilization and enhance the quality of soil as subgrade and foundation at large.

Keywords: Soft Soil, soil stabilization, nano-clay.

1. Introduction

In Malaysia, the development of national road networks, residential and commercial properties have encroached into the areas underlain with very soft soils. The soft clay has created a challenge to the construction industry, particularly in road construction. The characteristic of soft soil are high compressibility, low shear strength and low permeability. General construction problems in this deposit are insufficient bearing capacity, excessive post construction settlement and instability on excavation and embankment forming. In this formation, usually the hard layer and bedrock are very deep and results in higher cost of foundation. Geotechnical works in deep deposits of highly compressible soft clay is often associated with problems such as excessive differential settlement, negative skin friction and bearing capacity failure.

In order to counter these problems, one has to know the engineering properties of the soft clay. The conventional ground treatment methods such as soft soil replacement; expedite pore water dissipation and platform settlements through the insertions of prefabricated vertical drains (PVD) and surcharge fills; modify subsoil bearing capacity through the installation or stone column or combination of these techniques are widely used in Malaysia [10]. The applications of these methods are constrained by technical feasibility, space, time constraints and construction cost. Early selection and application of the most appropriate ground improvement techniques can improve considerably not only the design and performance of foundations and earth structures, including embankments, cut slopes, roads and railways but also result in their cost-effectiveness. Chemical stabilization methods are presented to provide soil strength improvement, mitigation of total and differential settlements, shorter construction period, reduced construction costs, and other characteristics which may impact on...
their utilization to specific projects on soft ground. This research addresses these deficiencies by creating Nano-clay by using Batu Pahat soft clay (BPSC) and performing testing laboratory stabilized soil using Batu Pahat soft clay (BPSC) Nano-clay as admixtures at Research Centre for Soft Soils (RECESS) [11].

Over the past 5 years, residential and commercial developments have increased in Batu Pahat. This development was constructed on soft clay. The civil engineering components of the project included construction of flood control, main drainage and access road. The construction on soft soil is increasing due to lack of suitable land for infrastructures and other developments. Imported soils from cutting of hills and highlands are used for various construction purposes. Many parts of Johor and other coastal areas consist of soft soils or peat soils. In this research, study is carried out in Batu Pahat district which is known to have abundance of soft clay. This type of clay called Batu Pahat soft clay (BPSC) is available up to a depth of 40 meters from ground level [2]. According to Hashim and Islam (2008)[3], roads in Batu Pahat district experienced many types of failures such as cracks, large surface deformation and structural deformation of pavement layers and the subgrade. They suggested that in order to reduce these failures, Batu Pahat soft clay needs to be utilized in order to reduce imported soil from other places and reduced the possibility of environmental damages. BPSC at Research Centre for Soft Soil (RECESS) has a plasticity index (PI) that range from about 36% to 46% in which the higher the PI, the greater the potential for problems [7]. Clays, especially highly plastic are subject to swell when their moisture content is increased. Moisture control is perhaps the most important single factor in the success of foundations on shrinking and swelling clays. The percentage of clay in a soil and the activity of clay minerals are reflected qualitatively by the value of the plasticity index. The larger content of clay minerals, and the more active the clay mineral, the greater is its potential for swelling, creep and changes in behavior. The Building research Establishment (BRE) suggests that the plasticity index over 35% provided an indication of volume change potential is very high. These volume changes can give rise to ground movements which can cause damage to buildings. Therefore, in order to prevent these problems, it is essential for engineers to stabilize the existing soil before commencing the construction activities. By stabilizing the soil, it is hoped that the soil will be more suitable as road subgrade and any road construction.

2. Soil Properties

Naturally occurring materials that are used for the construction of all except the surface layers of pavements (concrete and asphalt) and that are subject to classification test (ASTM D 2487) to provide a general concept of their engineering characteristics [1]. People describe soil types in all kind of ways such as heavy, light, clay and loam, poor or good. Soil scientist describes soil type by how much sand, silt and clay are present. This is called texture. It is possible to change the texture by adding different things. Changing texture can help in providing the right condition needed for plant growth. Sand is the largest particle in the soil. When you rub it, it feels rough. This is because it has sharp edges. Sand doesn't hold many nutrients. Silts are soil particle whose size is between sand and clay. Silt feels smooth and powdery. When wet, it feels smooth but not sticky. Clay is the smallest of particles. Clay is smooth when dry and sticky when wet. Soils high in clay content are called heavy soils. Clay also holds a lot of nutrients but doesn't let air and water through it well. Particle size has a lot to do with soils drainage and nutrients holding capacity. To better understand how this big three soil, we can imagine that if a particle of sand were the size of basketball, then silt would be the size of a baseball, and clay would be the size of a golf ball. Line them up, and we can see how these particle compare in size.

Construction of roadways over soft subgrade is one of the most common problems for highway construction in many parts of the world as well as in our country, Malaysia. The usual approach to soft subgrade stabilization is to remove the soft soil, and replace it with a stronger material of crushed rock. The high cost of replacement has caused highway agencies to evaluate alternative methods of highway construction on soft subgrade [10].
3. Nano-clay
The essential Nano-clay raw material is montmorillonite, a two to one layered smectite clay mineral with a platy structure. The thickness of each layer is about 1 nm, diameter from 10 nm to several microns, and the interlayer space around 1 nm depending on the modification methods. Due to its high aspect ratio and good physical and thermal properties, nanoclay has the potential for exceptional improvements in barrier, flammability resistance, thermal and mechanical properties. [5]

4. Stabilization
Stabilization is the process of blending and mixing with a soil to improve certain properties of the soil. The process may include the blending of soil to achieve a desired gradation or the mixing of commercially available additives that may alter the gradation, texture or plasticity, or act as a binder for cementation of the soil [1][3].

5. Soil Classification
Soil classification is a way of systematically categorizing soils according to their probable engineering characteristics. The classification of a soil is based on its particle distribution and, if the soil is fine-grained, on its plasticity (LL and PL). The most widely used classification systems used in road engineering are the unified soil classification system, AASHTO classification and British Standard Classification. Soil classification should only be regarded as a means of obtaining a general idea of soil behavior and it should never be used as a substitute for detailed investigation of soil properties [1].

6. Soil Engineering Properties
Engineering properties soil classifications have been evolved based on the suitability of a soil for use as a foundation material or as a construction material [8]. It was stated that engineering properties of soil are important as a preliminary guide to the engineering behaviour of the soil. Therefore, an engineering soil classification should be conducted in connection with the use of soil in any important project, since different properties govern the soil behaviour in different situations. Furthermore, the engineering properties are a function of the proposed end utilization [4]. The fundamental engineering properties of stabilized soil have been experimentally investigated by many researchers. The role of cement kiln dust and volcanic ash on the strength development in the blended cement admixed clay has been investigated for low-cost construction to build houses and road infrastructures [8].

7. Road Construction
Roads are built up in several layers, consisting of sub-grade, sub-base, base and surface layer. Subgrade is the uppermost part of the soil, consists of natural or imported soil to supporting the load transmitted from the overlying layers [6]. Therefore, sub-base course serves as an aid to disperse the load from the base course before transmitting it to the subgrade. The base course which is overlying the sub-base course plays a prominent role in the support and dispersion of the traffic loads. Surface course consists of binder course and wearing course. Binder course layer works as a supporting, dispersing traffic load and resists shear, while the topmost layer (wearing course) resists abrasion and prevent skidding. A soft subgrade in construction of roadways is one of the most frequent problems for highway construction in many parts of the world. These problematic soils do not possess enough strength to support the wheel loads upon them either in construction or during the service life of the pavement. The usual approach to soft subgrades stabilization is removes the soft soil, and replaces it with stronger materials likes crushed rock. The high cost of replacement causes highway contractors to explore alternative methods of highway construction on soft sub grades [8]. This soil must therefore, be treated to provide a stable subgrade or working platform for the construction of the pavement. One of the strategies to achieve this is soil stabilization. The soil stabilization includes both physical stabilization (such as dynamic compaction) and chemical stabilization (such as mixing with cement, fly ash, and lime). One of the most important layers of the road is the subgrade. Where the subgrade is
founded in an inherently weak soil, this material is typically removed and replaced with a stronger granular material.

8. Laboratory Testing

8.1. Atterberg Limits
Atterberg limit is a laboratory test that is performed to determine the plastic limit and liquid limit of soil. The plastic and liquid limit of BPSC is determined by using cone penetrometer test. By obtaining the value of plastic and liquid limit of BPSC, the plasticity index (PI) of BPSC can obtain.

8.2. Permeability
Permeability test is a laboratory test that is performed to determine the coefficient of permeability, k or the rate of water flow through the soil sample. The type of permeability test used is falling head test as it is suitable for fine grained soil. In this case, BPSC is used. The test results provide the rate of water seepage through the soil. (Refer Figure 3.1).

8.3. California Bearing Ratio
It is a penetration test for evaluation of the mechanical strength of road subgrades and base courses. The test is performed by measuring the pressure required to penetrate a soil sample with a plunger of standard area with equipments as shown in figure 3.1. The CBR rating was developed for measuring the load-bearing capacity of soils used for building roads. The harder the surface, the higher the CBR rating.

![Figure 3.1. Core Cutter for Permeability & CBR Test Equipment](image)

9. Results Analysis
The data gained from the completed experimental test were analyzed and discussed in this chapter. During the experimental process, the raw data, such as maximum dry density, the plasticity index, the coefficient of permeability, k and the CBR value for the soil were recorded. Their data were then processed and analyzed to determine the whether the soil gain more strength by using bentonite and nano clay as an admixture.

9.1. Optimum Moisture Content of BPSC
figure 4.1shows the optimum moisture content (OMC) of Batu Pahat soft clay (BPSC) is 16% and the maximum dry density is 1.774 Mg/m3. The compaction curve shown in the graph provides the relationship between the dry density and the water content for Batu Pahat soft clay subjected to a specific compaction effort.

9.2. Coefficient of Permeability, k of Different Percentage of Admixtures
figure 4.2 shows that the coefficient of permeability, k or the rate of seepage through BPSC with different percentage of admixture. The figure shows that the coefficient of permeability, k decreases from 0% of admixture to 15% of admixture. It shows that with increase of percentage of admixture in BPSC the rate of water seepage through the soil sample decreases almost linearly. Table 4.1 shows the coefficient of permeability, k for 0%, 5%, 10% and 15% of admixtures.

Table 4.1. Average Coefficient of Permeability, k.

| Percentage Of Admixture (%) | k Value Average (x 10^{-11}m/s) |
|----------------------------|-----------------------------|
| 0                         | 8.4750                      |
| 5                         | 5.7703                      |
| 10                        | 3.6950                      |
| 15                        | 2.0187                      |

9.3. California Bearing Ratio Value for Different Percentage of Admixtures
California Bearing Ratio (CBR) test is conducted to evaluate the strength of BPSC nanoclay whether it is suitable for the construction of road subgrade. The test is performed by measuring the pressure required to penetrate a soil sample with a plunger of standard area. The CBR rating was developed for measuring the load-bearing capacity of soils used for building roads. Figure 4.3, 4.4, 4.5 and 4.6 shows the CBR against the maximum dry density of BPSC with different percentage of admixtures.
Table 4.2 shows the CBR value interpreted from figure 4.3, 4.4, 4.5 and 4.6. Based on the value, it shows that the CBR value increases as the percentage of admixture in BPSC increases. This result is then compared with Table 4.3 which is the general rating of CBR.

![Figure 4.5. CBR against dry density for 10% admixture.](image1)

| Percentage Of Admixture (%) | Percentage Of CBR For 95% Dry Density |
|-----------------------------|--------------------------------------|
| 0                           | 10.1                                  |
| 5                           | 13.8                                  |
| 10                          | 14.1                                  |
| 15                          | 14.4                                  |

Table 4.3. General Rating of CBR.

| CBR Value       | Subgrade Strength | Comments                                         |
|-----------------|-------------------|--------------------------------------------------|
| 3% and less     | Poor              | "Capping is required"                            |
| 3% - 5%         | Normal            | Widely encountered CBR range capping considered according to road category |
| 5% - 15%        | Good              | "Capping" normally unnecessary except on very heavily trafficked roads. |

10. Conclusion
Based on the study, the following initial research conclusion of this project can be made.
1. The increasing of Bentonite and Nano clay decreases the void in BPSC. When the void in BPSC decreases, the rate of water flowing through the soil also decreases thus improving the soil and is suitable for road subgrade.
2. The CBR value for BPSC increases when the percentage of Bentonite and Nano clay increases thus increasing the strength of BPSC. High value of CBR shows that the strength of the soil is good.
3. The admixture used which is Bentonite and Nano clay are suitable additives for strengthening of soil and can be used to improve the quality of weak road subgrade.

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