Effectiveness of different admixtures on Atterberg limit and compaction characteristics of stabilized soil

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Abstract. Index properties of soared are the most crucial part of the soil, which impact construction activities due to the rapid growth of urbanization and industrialization. Soft soil is one of the most unstable soil which has a low strength and stiffness index due to its high liquid limit. Stabilization of soil by adding chemical or non-chemical based such as lime and cockle shell powder have proven to improve the index properties of soft soil. Lime and cockle shell powder is the most popular reinforcement materials used in the study on the soil reinforcement for soft soil. The use of lime and cockle shell powder as reinforcement materials in soil are proven effective. The study’s objective is to investigate the effectiveness of different admixtures used in the soil stabilization compared to lime and cockle shell powder on the effect of Atterberg limit and compaction characteristics of soft soil. It is shown the soil reinforcement in soil stabilization is functionally in improving mechanical properties of the soft soil. Meanwhile, the admixture in powder formed to act as a fine binder between soil and stabilizer agents. This will enhance the index properties of original soft soil such as Atterberg limit and compaction characteristics.

1. Introduction
The construction of roads on the soft soil condition will cause various problems during the construction itself. The lifetime of the road is also affected by the soil condition. Soil improvement must be done to avoid such problems in the future. The stabilization using the admixtures technique is the method of mixing the soil with additional additives. Soils that do not feature in-demand characteristics for a particular construction can be reinforced by adding one or more stabilizers. The addition of a stabilizer can improve the geotechnical competency of the ground.

As the soils suitable for construction are limited, the weak soils need to be strengthened before head. The lime and cockle shell powder is used to stabilize the clay soil. The mixed stabilizers are used for the experimental observation. This method will increase the quality of the soil. Stabilization utilizing soil admixtures can also decrease the soil's compressibility and hydraulic conductivity. This study is also supported by the previous studies research.
Cockle shell is a waste material that can be found near the seaside area. Cockle shell contained 90% of calcium carbonate and 10% of dust and impurities. It has similar content of cement additives and lime binder [1-2] which include calcium carbonate and calcium oxide. The use of cockle shell powder in soil stabilization will reduce environmental impact in carbon emission as well as by inserting the stabilizer in the subgrade layer enhance the durability of the soft soil [3-5].

Lime is in the form of quicklime (Calcium Oxide - CaO). Quicklime is made by converting calcium carbonate as it has been transformed chemically from calcareous to calcium oxide. The effectiveness of lime in stabilization soil has been shown in improving soft soil properties [6-9].

2. Methodology

Soft soil was collected from the area of the construction site next to the Sunway Carnival Mall at 3068, Jalan Todak, Pusat Bandar Seberang Jaya, 13700 Seberang Jaya, Pulau Pinang. The soil samples were obtained through open digging at a depth of 7 m below ground level. The total soil samples collected were 50 kg. The soil samples were taken back to the laboratory to examine the index properties.

Meanwhile, for admixture used in soil stabilization were cockle shell powder and lime where cockle shells were collected from Pulau Aman, Kedah. The cockle shells were taken to the laboratory for preparation as in powder. The plain water was used to wash the cockle shells. The cleaned cockle shells were placed in the tray for 24 hours to be dried oven. After 24 hours, the dried-oven cockle shells were withdrawn. Then the cockle shell was dried and crushing to a powder form. Before the grinder process, the cockle shells had been compressed into smaller particles. The cockle shells went through the grinding process and became powder cockle shells. Lime powder was produced by manufacturing for stabilization purposes.

3. Results and Discussions

Table 1 shows an index property of soft soil before went through the stabilization process. The soil is classified as high plasticity of CLAY.

| Soil properties          | Value  |
|--------------------------|--------|
| Specific gravity, Gs     | 2.48   |
| Plastic limit, PL (%)    | 36.67  |
| Liquid limit, LL (%)     | 68.37  |
| Plasticity index, PI (%) | 31.70  |
| Classification of soil   | CH     |

Next, soil stabilization was carried out with the soil reinforcement by 16% of lime and 16% of cockle shell powder [10] at optimum content of additive. The value of liquid limit, 36.60% is obtained from the curve at 20 mm cone penetration depth as can be seen from Figure 1. From the curve in Figure 1, at 20 mm cone penetration depth, the liquid limit of soil with additives seems to be decreased. Adding these two admixtures strengthen the soil structure by reducing the amount of water content thus the consistency limit of soil in the liquid limit state [11].
Figure 1. Liquid limit after stabilization process.

Figure 2 shows the maximum dry density (MDD) and optimum moisture content (OMC) of the original soil sample is obtained from the highest peak value of the compaction curve. Based on Figure 2, shows the value of OMC and MDD is 20.24% and 1.563 Mg/m³ respectively. The maximum dry density of soil obtained can be used in the specification of field compaction. The compaction of soil will also reduce the moisture content and void between soil mixtures thus increase the dry density and strength of the soil.

Figure 2. Compaction characteristics after stabilization process.

In a comparison of the effectiveness of cockle shell powder and lime in the stabilization process on Atterberg limit and compaction characteristics effects, few data collection of various admixtures were collected from previous studies and shown in Figures 3, 4 and 5. It shows in Figure 3 the effectiveness of using the admixtures in soil stabilization enhance the consistency limit of the soils as the original liquid limit decreased after adding the stabilizers. The fibre acts as reinforcement in soil stabilization thus show less amount of water decrease after adding into original soil.
Meanwhile in Figure 4 shows the plasticity index is low when adding lime, cement and polypropylene fibre with brick powder shows less significance in soil stabilization as it acts as reinforcement in the soil mixture. The use of soil reinforcement as a mechanical means of stabilising weak of the soil grains into a unit mass of improved mechanical performance. From Figures 3 and 4, it can conclude the soil is classified as highly plasticity for the plasticity index of the soft soil. Figure 5 shows soil classification and plasticity index for various types of stabilizers with the highest percentage of soil plasticity and lowest percentage of medium to low plasticity of soils. The plasticity index of stabilized soils is relied on mineral contents of natural soils as well as the stabilizer contents influence the Atterberg limit as agreed with Zhang and Charkley [12].
The effectiveness of various concentrations of mix stabilizers towards the index properties of soil is proven by the previous studies which are shown in Figure 6-10. These figures are showing the various values of maximum dry density and optimum moisture content which depend on the type of stabilizer. All the figures show that the optimum moisture content is decreasing, while the maximum dry density is increasing. A similar trend was found from Zhang and Charkley [12], the dry density increased with an increase in moisture content until optimum and then began to decrease with any further increase in moisture. The influence of stabilizers in the soil mixtures may change the compaction characteristics for different admixtures. The increasing of maximum dry density makes the stabilizer a good material and is effectively used in soil stabilization.
Figure 7. Variation of maximum dry density and optimum moisture content of soil mix with polypropylene fibre + brick powder.

Figure 8. Variation of maximum dry density and optimum moisture content of soil mix with fly ash + sand.
Figure 9. Variation of maximum dry density and optimum moisture content of soil mix with cement + lime.

Figure 10. Variation of maximum dry density and optimum moisture content of soil mix with cement + molasses.

4. Conclusion
In this study, the effectiveness of various admixtures in soil stabilization is found from current and previous findings. It is shown the soil reinforcement in soil stabilization is functionally in improving mechanical properties of the soft soil. Meanwhile, the admixture in powder formed to act as a fine binder between soil and stabilizer agents. This will enhance the index properties of original soft soil such as Atterberg limit and compaction characteristics.
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