Soft Soil Improvement for Sub-grade Layer Using Hexagonal Micropiles Layout

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Abstract. Soft soil problems are often associated with sediment and stability where it represents a major challenge in Geotechnical Engineering. Research on a soft soil was carried out to determine the level of sediment resulting from the applied load and thus compare the most ideal form of arrangement by the results obtained from bearing capacity. The study was conducted at Research Centre for Soft Soil (RECESS), UTHM by using kaolin. There are several tests conducted on kaolin before the arrangement of pile which is liquid limit test. Through these tests, the level of water content can be maintained which is 1.2 liquid limit where it is in the homogeneous condition. Density test also carried to know weight of kaolin and water that needed in the model. Meanwhile, large strain consolidation test carried on the soil by placing a load of 8 kPa. Then, the pile was arranged in the soil in the shape of a hexagon and square. Load was increased to 12 kPa and imposed on the surface of the pile with a different forms. After 24 hours, the reading of sediment was measured everyday and the process collecting data conducted for 3 week. Based on data obtained, time against sediment can be plotted. To determine the bearing capacity, direct shear test was conducted to get the value coefficient of cohesion, c as a parameter in the calculation of the soil bearing capacity. The results showed that the rate of settlement occurs is different where hexagonal form less the rate of settlement compared to square form which is 64.2% while the results of bearing capacity have the same value.

1. Introduction

Soft clay defined as soil that has a weak strength, high compressibility and most are very sensitive, so its strength is easily influenced by interruption. Besides, in Soft Clay Engineering, the soft clay settlement will spread widely and often cause problems in terms of engineering design and construction. The common case happen is foundation failure in soft clay and loading surface of shallow foundation inevitable due to the large settlement occurs where construction design should be suitable and require maintenance through engineering facilities [1].

Soft soil has features such as high compressibility, shear strength is low (< 25kPa) and the soil is easily distracted [2]. Among factors occurrence of sediment is caused by compression and strengthening of soil under the building structure, high dynamic loading, digging in the area close to the building
structure and the change of water level surface [3]. Soil that has been through the process of stabilization will become stronger, waterproof, durables and enhance soil bearing capacity [4]. Factors such as the strengthening process of base soil, the irrigation system is not suitable, the weak embankment soil compaction, changes in weather and temperature as well as others contribute to this failure [5].

Durability of mangrove piles depends on condition where it should always be in wet condition all the time. Based on the test specimen [6] reported that mangrove piles that are on dry soil was decay bitten by termite or fungus after 3 years while untreated mangrove pile driven at a depth fully of water still in a good condition after 5 years. Based on JKR standards, the characteristics of mangrove piles used are size between 75 mm to 125 mm diameter, the normal length of 6m to 12m with one connection and allowable load to be within 5kN to 10kN per piles.

Selection of a suitable subgrade layer is important to be a basis of certain construction to determine whether the ability of construction surface accommodated the stress load transmitted through the vertical and horizontal [7]. Subgrade layers need to review to get the best layer. This method aims to evaluate the system of particular structure that requires observation and consideration of engineering. The development of science and technology has created a variety of alternative methods of reducing soil sediment impact such as pre-loading of draining, vibroflotation and treatment with chemicals such as lime, electro-osmosis and other methods [2].

This research focuses on the shape of a hexagon where utilization of hexagonal shape begun to be applied in the construction either inside or outside the country. There are few examples of overseas construction that have used the hexagonal shape. Invention [8] relates to the basic construction elements that channel bank can be made easily and economically. Block pavement was introduced by [9] and has also applied in Malaysia for pavement utilization in a several methods of consecutive block arrangement. Interlocking glass block system applied by [10] where this invention is generally related to glass block in wall construction, space restrictions, and the panel. [11] creation of modular structures and more particularly to the construction of hexagonal modules that are easy to install, low-cost of materials and can be adapted for various uses such as living room, working room and container for shipping or storage. Creation hexagonal tiles by [12] with the same side of reinforcement for use in modular floor assembly as used in the area of sports games.

Therefore, the objectives of this study are to determine the bearing capacity of the pile in soft soil and to design the layout of the pile using a hexagonal shape. Also, this study was conducted to determine the sediment rate occur against arrangement of the pile in a hexagonal shape when the load imposed on it. Next compare the most ideal of arrangement form by the results obtained from bearing capacity.

2. Materials and Methods

Methodology is divided into two parts to describe how the study was conducted. First part was the preparation for mini-scale model (material and design), and the second part was sample preparation (Kaolin layer).

2.1. Preparation of mini-scale Models

Two mini-scale models were made using steel size of 40cm x 40cm x 60cm to compare methods of arrangement pile in the most ideal form. Valves pipe are installed 5cm from bottom surface at front and back of model to discharge water during the process of preloading. At front of the model there is a glass size of 2.5cm x 50cm (see Figure 1). On both the left and right of the glass there is a measuring tape to
view and read the settlement that occurs every day (see Figure 2). The frame is placed on the inside of the model to strengthen the structure during loading process.

Material preparation involves the use of bamboo as a pile with size of 30cm in length where it has been ratio to 1:20, 1.4cm diameter and involves the use of 16 bamboo sticks for both models where 7 pile for hexagon shape and 9 pile for square shape. Besides that, there is preparation of geotextile layer with size 50cm x 50cm to avoid aggregate mixed with kaolin layer. At the top layer, rigid steel plate size 35cm x 35cm is provided which functions as a layer for spreading the load applied to pile next transmitted to the ground.

![Figure 1. Steel formwork used for Mini-scale Model](image1)

![Figure 2. Front view side of Mini-scale Model](image2)
Figure 3. Bamboo sticks were used as mini Micropiles

2.2. Sample preparation

Sample of clay used in these experiments is kaolin in RECESS, UTHM. Kaolin has undergone Liquid Limit Test to obtain percentage of moisture content. Similar of soil properties were maintained by counting 1.2 Liquid Limit, so that the soil in homogenous condition. The weight of kaolin and water in the model was determined through Density Test. The volume of kaolin is required in the model was 0.0752 m$^3$ where the length and width of model equal to 0.4 m x 0.4 m and high is 0.47 m. Thus, weight of the kaolin, was calculated at 64.20 kilogram and 50.10 liter of water.

The bottom layer is aggregate size between 2 mm to 5 mm put in the model with height of 8 cm. The aim placed the aggregate is to accelerate the water discharge. Next, layer of geotextile is placed to prevent aggregate layer mixed with kaolin. 5cm space at the top will emptied for placing sample of pile. Thus, kaolin was filled with 55cm height (depth). After kaolin placed into the model, it was imposed by load of 8 kPa and left for a week with opened valve to remove the excess water contained therein.

After a week, the piles were arranged on the surface of the soil according to form respectively at the two models that have been provided. Figure 4 and Figure 5 show the pile arrangement form for the two models. Load was increased to 12kPa and imposed on the surface of the pile in different shapes. Valve is closed during test running. After 24 hours, the readings of the sediments were measured every day and the process of collecting data conducted for the three weeks.
3. Results and Discussions

According to laboratory test that was carried out in RECESS UTHM, several results obtained. Discussion carried out through the comparison of settlement rate occur between pile arrangement of hexagonal shape compared with square shape, the bearing capacity for two forms of pile arrangement and a hexagonal layout design proposal of mangrove pile.

3.1 Analysis of Large Strain Consolidation Test

Based on the data obtained from the tests that have been carried out, the settlement rates can be compared. Figure 6 shows comparison of settlement both forms can be seen which is sediment of a square shape is 33.50 mm while hexagonal shape is 12 mm. Therefore, hexagonal shape less of settlement rate compared to squares shape about 64.2%. 

Figure 4. Arrangement pile of Square Form layout

Figure 5. Arrangement pile of Hexagon Form layout
3.2 Analysis of Bearing Capacity

Based on the calculation of the bearing capacity, the two forms of the pile arrangement get the same value of 0.0434kN. Table 1 showed the results of bearing capacity. Comparison can be seen through the number of pile used in the arrangement where arrangement of a square shape using a number of piles is 9 while the hexagonal shape is 7. Therefore, hexagonal shape can reduce the use of pile in terms of cost and represent an ideal form of saving space.

| Shape     | Square (kN) | Hexagon (kN) |
|-----------|-------------|--------------|
| Bearing Capacity | 0.0434      | 0.0434       |
| Number of piles | 9           | 7            |

3.3 Analysis of proposed Hexagonal layout arrangement

The sizes of mangrove pile are between 75 mm to 125 mm. Therefore, there are two proposals for the design hexagons layout by proposing the use of the minimum and maximum size. Figures 7 and 8 showed the design of hexagonal layout proposal. Based on the diameter size of mangrove, the distance between pile and the calculation of a hexagonal layout of the subgrade layer can be proposed.
4. Conclusion

In conclusion, the objective of this study was achieved where to determine the bearing capacity of the pile in soft soil and design the layout of the pile using a hexagonal shape. Therefore, it is hoped that hexagonal form can be applied in actual piling process in the field of construction since this form is more economical because it uses a fully space in the suggestion of hexagonal layout designs that have been proposed. In addition, stability, strength and stiffness of a hexagonal shape is hoped to be a form that will be used widely in civil engineering.

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