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Study bearing capacity of subgrade using combination bamboo grid and stabilized soil

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ABSTRACT

The subgrade of road construction also determines the strength and resistance to loads on it. The subgrade in the field very varies from soft clay to hard soil. The subgrade of soft clay requires soil improvement to increase bearing capacity. This study aims to determine the increase in bearing capacity and modulus of subgrade reaction in stabilized soil with the bamboo grid. The research was conducted through a physical model using a test box. Soft clay is compacted and the above it is replaced with stabilized soil with and without the bamboo grid. The height of stabilized soil varied from 0-15 cm. The results showed that the bearing capacity increased along with the increase in height of stabilized soil. The subgrade of stabilized soil which was given additional reinforcement of bamboo grid was able to increase the value of bearing capacity and modulus of subgrade reaction. A significant increase was obtained in the height of stabilized soil at least equal to the diameter of the test plate.

Keywords: bearing capacity; modulus of subgrade reaction; plate load test; subgrade

1 Introduction

Soft clay has unfavorable properties when used as a road subgrade. This type of soil has high content, high liquid limit and plastic index, low shear strength, low California Bearing Ratio (CBR) value, and low bearing capacity [1]. Soft clay has a high settlement and needs a reinforcement system to support the load of the embankment [2]. In addition to embankment loads, subgrades need to support other construction loads.

Subgrades for road pavements generally have the bearing capacity that can still be achieved. This can be seen from the value of the CBR above 6%, still smaller than the railway subgrade which has a minimum CBR of 8% [3]. The low bearing capacity of the subgrade can have an effect on non-optimal pavement performance. For this reason, it is necessary to make efforts to increase the bearing capacity of the subgrade with soil stabilization or through the use of soil reinforcement.

Soft clay stabilization is conducted by mixing a stabilizing agent such as cement or lime [4]. Several studies related to soil stabilization, such as biogrouting, lime, and pozzolans. Soil stabilization with the biogrouting method is conducted on organic soil [5]. Using lime and pozzolans for soil stabilization in the subgrade of pavement construction [6]. In addition to the use of cement, rice husk ash can also be used as a stabilizing agent for clay soil [7]; [8]. Stabilization of clay can be done by using fly ash [9]. These soil stabilizing agents show improved soil properties.

Another alternative to subgrade improvement can be done through the installation of reinforcement on the subgrade. Soil reinforcement can be installed vertically or horizontally. Vertical soil reinforcement can use piles of various materials such as concrete, wood, or bamboo [10, 11, 12, 13, 14]. Pile reinforcement is suitable for a fairly thick layer of soil, but it is better to use horizontal reinforcement for soil improvement on the surface. Reinforcement systems can use materials such as geosynthetics or other local materials. Several studies on soil reinforcement have had a good impact on improving the performance of subgrade. Geotextile can be used as a reinforced expansive soil subgrade [15].

Local materials such as bamboo continue to be developed to be used as soil reinforcement. This reinforcement is installed horizontally on the soft clay layer. The performance of the bamboo grid contributes to increasing bearing capacity and reducing soil settlement. This can be seen from the results of several studies [16, 17, 18, 19, 20, 21, 22, 23]. The bamboo grid reinforcement system is generally used as reinforcement in soft clay and peat soils. This reinforcement needs to be reviewed for its performance if it is used as soil reinforcement from soil that has been stabilized first.

The performance of bamboo grid reinforcement can be seen from the two-stage soil improvement system. The first stage is soil improvement by stabilization using 9% stone ash without reinforcement and the second stage is conducted by using a bamboo grid as reinforcement on the stabilized subgrade. This study aims to show the increase in bearing capacity (q_u) and modulus of subgrade reaction (k) in stabilized soil with the bamboo grid.

2 Data and Methods

The research material used soft clay, bamboo grid, and stone ash as soil stabilization material. Soft clay was stabilized with stone ash as much as 9% of the dry weight of the soil. Reinforcement of the bamboo grid widens the area of pressure in the soil, this widening can increase the mobilization of friction between the bamboo grid layer and the soil, so that the bearing capacity of the soil increases [24].

The soft clay soil is compacted in a test tank according to the density of the original soil in situ. Soil density in the test box can be determined from the core cutter test which is taken every 10 cm thick in several soils. The core cutter method is used to determine the density of the soil placed in the test box. This method is conducted by pressing the ring in the soil through the penetration of the core cutter so that the weight of the soil in the ring can be used to determine the density of the soil.

Soil samples were compacted in a test box measuring 1 m × 0.9 m × 0.9 m. The test box is made of steel plate which is reinforced with the steel frame. The solid material of gravel and sand is placed at the bottom of the test box to 0.4 m, then on top of it the soft clay is compacted gradually layer by layer until it reaches a thickness of 0.5 m. Subgrade consists of two types namely stabilized soil with and without the bamboo grid. Model testing is done by forming a square measuring 30 cm x 30 cm with a stable soil depth of 5 cm and 15 cm, respectively. Stabilized soil is compacted according to the density of the compaction test results. Bamboo grid reinforcement was installed in 1 layer for stabilized soil with a depth of 5 cm and 3 layers for stabilized soil with a depth of 15 cm. Test preparation can be seen in **Figure 1**.

The test plate with a diameter of 15 cm was placed in the center of the surface of the stabilized soil, both reinforced with bamboo grids and without bamboo grids. The load test with the proving ring is conducted in the center of the test plate. The plate load test is shown in **Figure 2**.

The bearing capacity of the subgrade was analyzed based on the results of the plate load test (ASTM-1194, [25]). Based on the relationship between pressure and settlement curves, the bearing capacity values of each test model are obtained. The pressure is obtained from the load divided by the area of the test plate. The load can be determined from the reading of the proving ring multiplied by calibration number. Pressure per deformation can be used to analyze the value of the modulus of subgrade reaction.

Figure 1. Test preparation

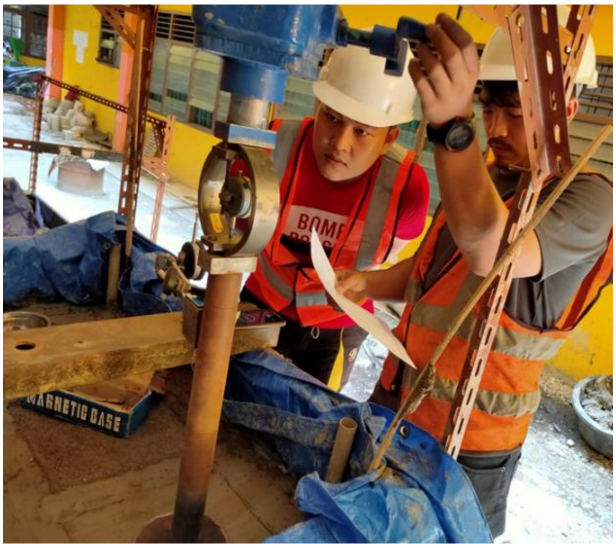

Figure 2. Plate load test in test box

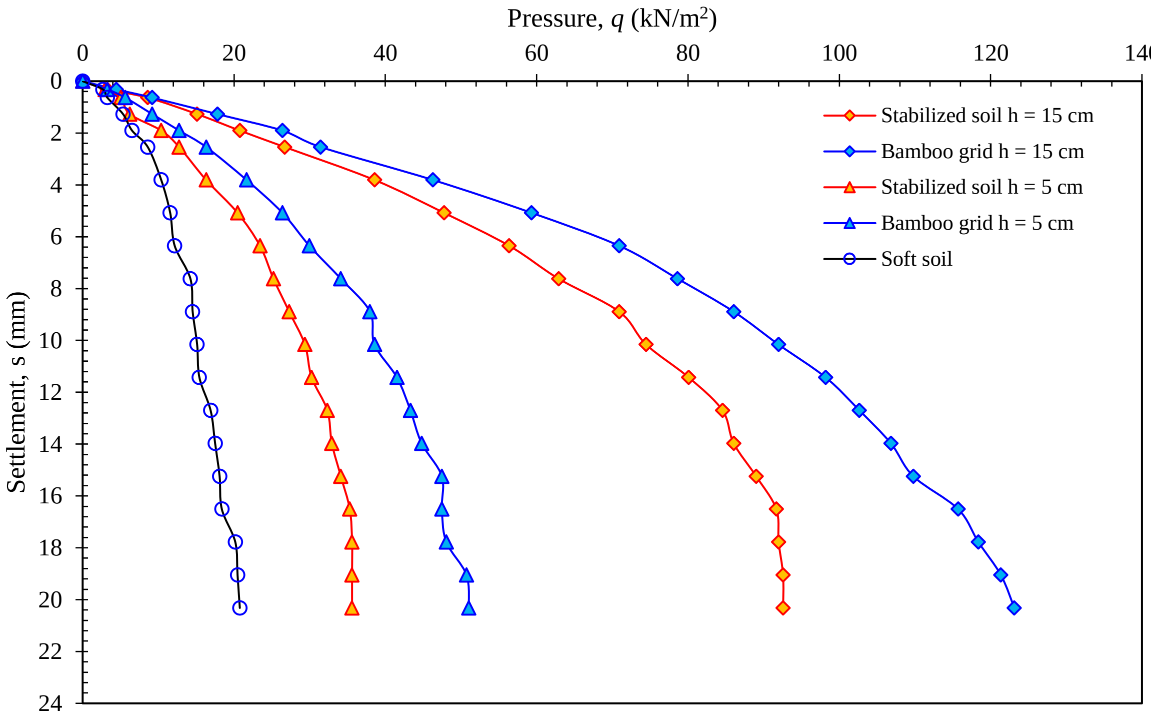

Figure 3. Result of plate load tests of subgrade

3 Results and Discussion

The results of the study describe the results of the plate load test on soil with a combination of bamboo grid reinforcement and stabilized soil compared to stabilized soil only without the bamboo grid. The soil used is clay with the moisture content of 73.70%, specific gravity of 2.64, liquid limit of 57.27%, plastic limit of 36.07%, plastic index of 21.20%, and fined grained soils are 97.56%. Stabilized soil is soft clay that is stabilized using stone ash as much as 9% of the dry weight of the soil. The maximum dry density of stabilized soil was obtained from the compaction test of 1.39 gr/cm^3 and the optimum moisture content of 27.12%.

3.1 Result of Plate Load Tests

Figure 3 shows the result of plate load tests of subgrade the stabilized soil with and without bamboo grid. The plate load tests are conducted at each point of subgrade from stabilized soil which is distinguished based on the thickness of the stabilized soil layer 0-15 cm. Subgrade from stabilized soil respectively with and without the bamboo grid. The combination bamboo grid and stabilized soil gave higher yields than stabilized soil without the bamboo grid for both *h* of 5 cm and *h* of 15 cm.

3.2 Analysis Results of Bearing Capacity

Analysis of bearing capacity (q_u) was obtained from the relationship of pressure-settlement curves from the plate load test. Typical relationship between pressure and settlement curves can be seen in **Figure 4** and **Figure 5**. **Figure 4** is the result of the test on a combination of bamboo grid and stabilized soil. **Figure 5** is the result of the test on stabilized soil only.

Typical pressure-settlement curves of plate load tests are not much different from each other. The bearing capacity can be determined for each plate load test for both combination bamboo grid and stabilized soil and stabilized soil without the bamboo grid.

The results showed that the higher the pressure along with the increase in the thickness of the stabilized soil. The pressure for the combination of the bamboo grid and stabilized soil is higher than that for stabilized soil without the bamboo grid. The bamboo grid contributes to the increased pressure in the subgrade layer.

3.3 Bearing Capacity of Combination Bamboo Grid and Stabilized Soil

The value of bearing capacity of combination bamboo grid and stabilized soil can be seen in **Figure 6**. The results showed that the increase in bearing capacity was influenced by the thickness of the stabilized soil layer. Reinforcement of the bamboo grid effects increasing the bearing capacity of stabilized soil. The increase in bearing capacity was obtained from 217-733% for the combination of bamboo grid and stabilized soil, while without the bamboo grid the increase in bearing capacity was 188-608%. Due to the addition of bamboo grid reinforcement, the bearing capacity of stabilized soil increased by 10-18% from stabilized soil without the bamboo grid.

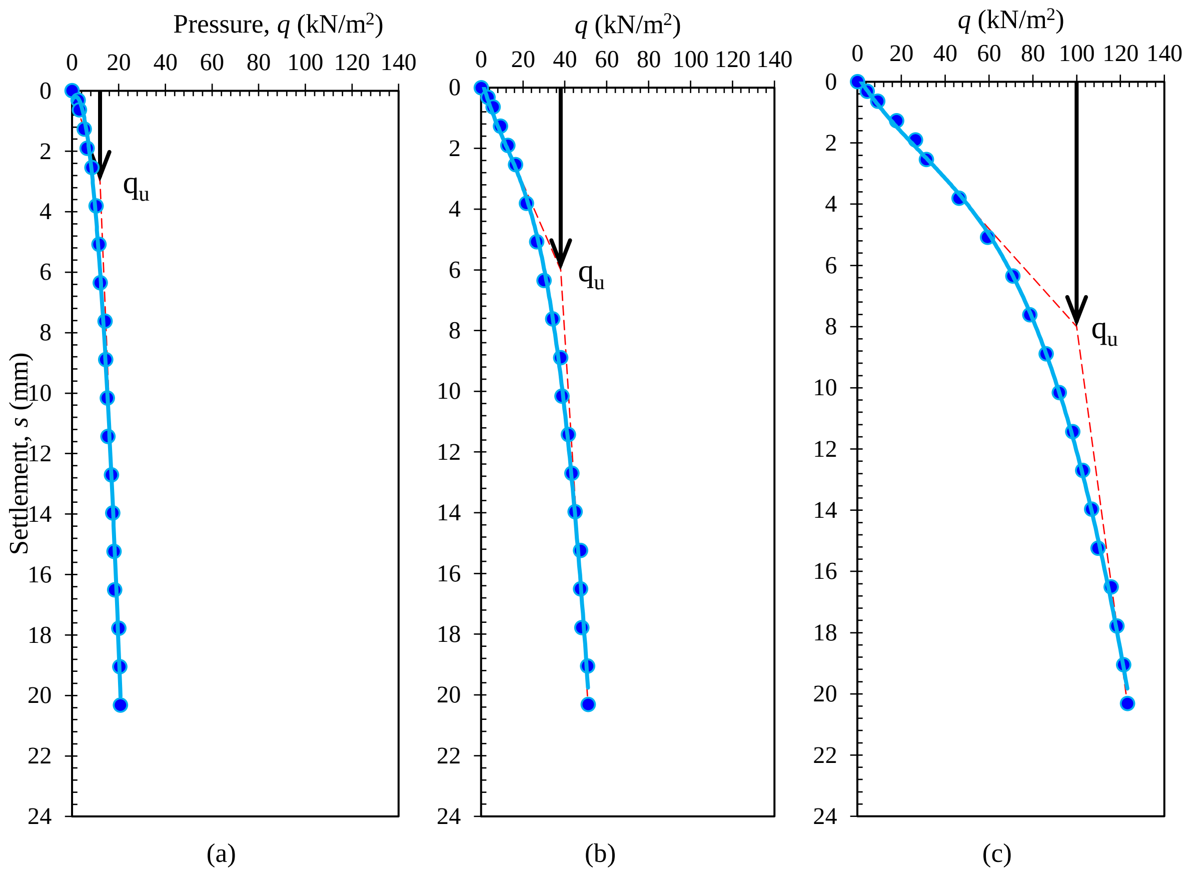

Figure 4. Pressure vs settlement – bamboo grid: (a). h of 0 cm; (b). h of 5 cm; (c). h of 15 cm

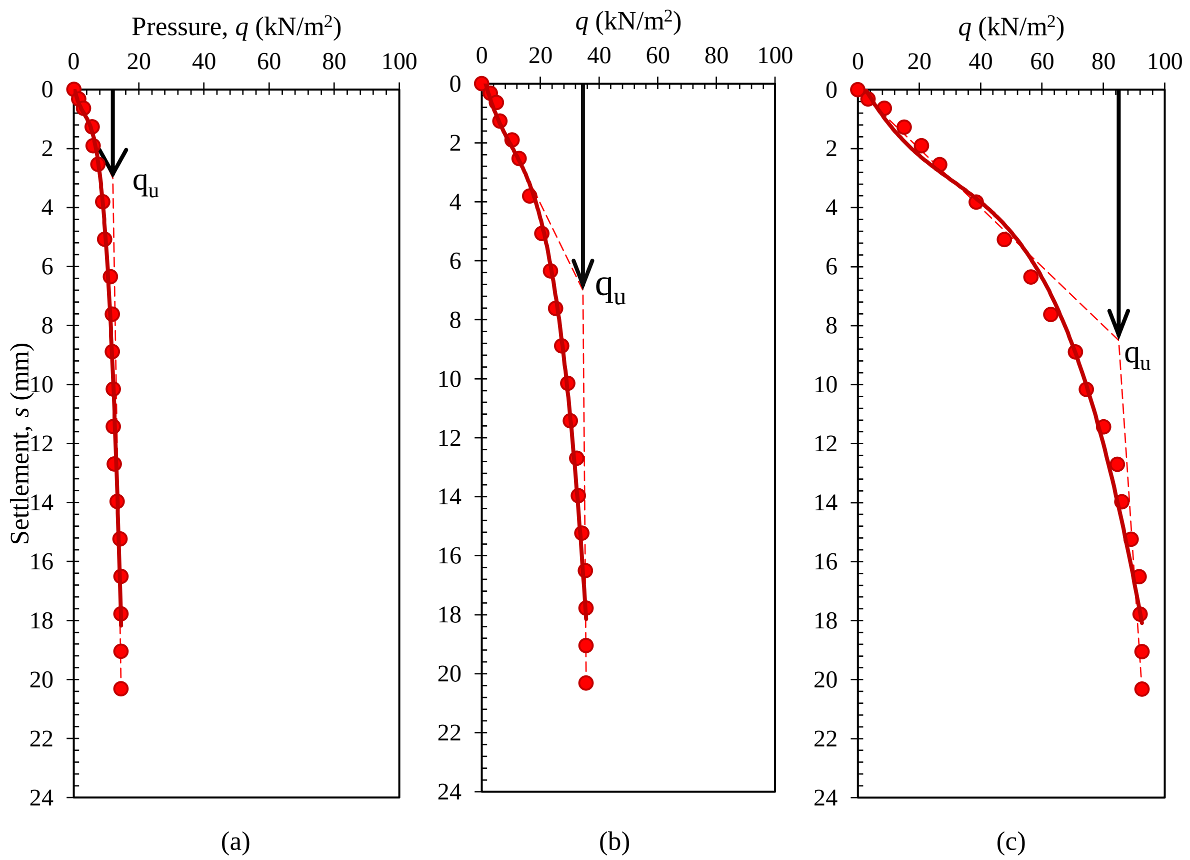

Figure 5. Pressure vs settlement – stabilized soil: (a). h of 0 cm; (b). h of 5 cm; (c). h of 15 cm

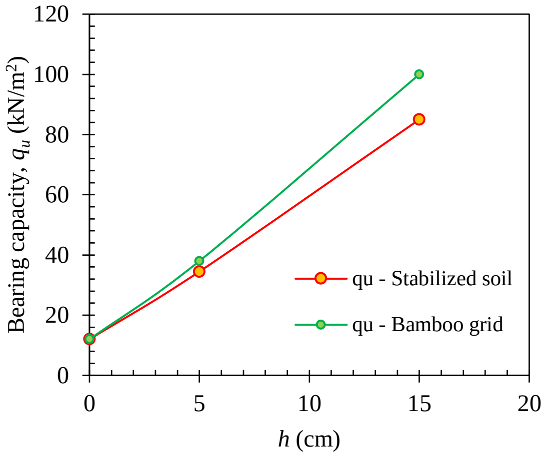

Figure 6. Bearing capacity and height of stabilized soil

The same behavior is seen in the bearing capacity ratio ($q_u/q_{u\text{-}o}$) relationship and the ratio of stabilized soil thickness to plate diameter (Figure 7). The value of $q_{u\text{-}o}$ is the bearing capacity of soft clay and q_u is the bearing capacity of stabilized soil with and without the bamboo grid. A significant increase in bearing capacity was obtained at the thickness of the stabilized soil equal to the diameter of the test plate. So it can be interpreted that the thickness of stabilized soil is at least equal to the width of the plate. As an application for the foundation plate, the thickness of the stabilized soil can be taken greater than the width of the foundation plate.

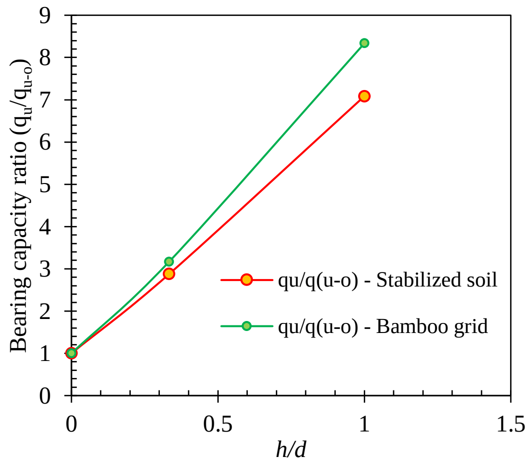

Figure 7. Bearing capacity ratio vs h/d

The modulus of subgrade reaction (k) can be determined from the pressure per deformation of soil settlement of the subgrade. The results of the analysis can be seen in **Figure 8**. The value of k is 6333-12500 kN/m^3 for the combination of bamboo grid and stabilized soil, while without the bamboo grid the modulus of subgrade reaction is 4929-10000 kN/m^3. The k values provide a significant increase from the k value of the soil without stabilization and reinforcement of 4000 kN/m^3.

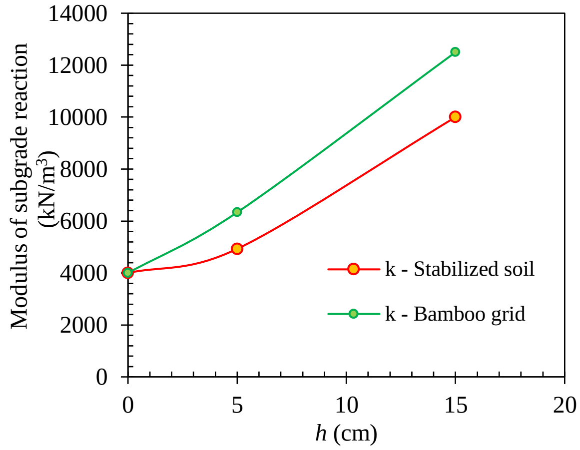

Figure 8. Relationship modulus of subgrade reaction and height of stabilized soil

4 Conclusion

Based on the results of this study and discussion, the conclusions obtained several important things. Soil improvement with stabilization has an impact on increasing the bearing capacity (q_u)of the subgrade. The bearing capacity will increase when combined with reinforcement from the bamboo grid. The thickness of stabilized soil influences on the value of the q_u of the subgrade. This study shows that the minimum thickness of stabilized soil should be equal to the diameter of the test plate. In addition to bearing capacity, the value of modulus of subgrade reaction (k) showed an increase in stabilized soil both with bamboo grid and without the bamboo grid. The reinforcement of the bamboo grid contributes to an increase in q_u and k value.

References

[1] R. C. Omar and R. Jaafar, "The Characteristics and Engineering Properties of Soft Soil at Cyberjaya," in *Geological Society of Malaysia Annual Geological Conference 2000*, 2000, pp. 313–322.

[2] A. S. Balasubramaniam, H. Cai, D. Zhu, C. Surarak, and E. Y. N. Oh, "Settlements of Embankments in Soft Soils," *Geotech. Eng.*, vol. 41, no. 2, pp. 1–19, 2010.

[3] A. Waruwu, M. Arfan, and T. O. Waruwu, "The Behavior of the Perbaungan Railway Subgrade," *J. Infrastruct. Plan. Eng.*, vol. 1, no. 1, pp. 46–50, 2022.

[4] F. Varela, E. Cerro-Prada, and F. Escolano, "Preparation, Characterization and Modeling of Unbound Granular Materials for Road Foundations," *Appl. Sci.*, vol. 8, no. 9, p. 1548, 2018.

[5] J. Widjajakusuma, M. Sugata, A. Changgrawinata, L. Jap, A. Zacharia, and T. J. Tan, "Study on tropical organic soil stabilization based on biogrouting," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 620, no. 1, 2019.

[6] Z. Yin, R. L. Lekalpure, and K. M. Ndiema, "Experimental Study of Black Cotton Soil Stabilization with Natural Lime and Pozzolans in Pavement Subgrade Construction," *Coatings*, vol. 12, no. 1, p. 103, 2022.

[7] J. Widjajakusuma and H. Winata, "Influence of Rice Husk Ash and Clay in Stabilization of Silty Soils Using Cement," *MATEC Web Conf.*, vol. 138, 2017.

[8] X. Jiang, Z. Huang, F. Ma, and X. Luo, "Analysis of Strength Development and Soil-Water Characteristics of Rice Husk Ash-Lime Stabilized Soft Soil," *Materials (Basel).*, vol. 12, no.

23, pp. 1–19, 2019.

[9] S. Striprabu, S. N. L. Taib, N. M. Sa'don, and A. Fauziah, "Chemical Stabilization of Sarawak Clay Soil with Class F Fly Ash," *J. Eng. Sci. Technol.*, vol. 13, no. 10, pp. 3029–3042, 2018.

[10] A. Waruwu, R. D. Susanti, H. S. Sihombing, and T. Y. Purba, "Pengaruh Susunan Tiang dengan Grid Bambu pada Tanah Gambut Terhadap Lendutan," in *Semnastek UISU*, 2020, pp. 9–15.

[11] A. Waruwu, H. C. Hardiyatmo, and A. Rifa'i, "Behavior of Nailed-Slab System on Peat Soil Under Laoding," in *The 1st Warmadewa University International Conference on Architecture and Civil Engineering*, 2017, pp. 91–97.

[12] A. Waruwu and M. T. Silalahi, "Kajian Jarak Tiang Perkuatan pada Tanah Gambut," *J. Tek. Sipil Unaya*, vol. 8, no. 1, pp. 1–10, 2022.

[13] A. Waruwu, H. C. Hardiyatmo, and A. Rifa'i, "Deflection Behavior of The Nailed Slab System-Supported Embankment on Peat Soil," *J. Appl. Eng. Sci.*, vol. 15, no. 4, pp. 556–563, 2017.

[14] A. Waruwu, H. C. Hardiyatmo, and A. Rifa'i, "The Performance of The Nailed Slab System-Supported Embankment on Peat Soil," *Int. Rev. Civ. Eng.*, vol. 10, no. 5, pp. 243–248, 2019.

[15] N. Tiwari and N. Satyam, "An experimental study on the behavior of lime and silica fume treated coir geotextile reinforced expansive soil subgrade," *Eng. Sci. Technol. an Int. J.*, vol. 23, no. 5, pp. 1214–1222, 2020.

[16] A. Waruwu, F. Gea, J. Y. A. H, E. M. W, and M. Zega, "Pengaruh Model Perkuatan Bambu Terhadap Nilai CBR Tanah Lempung Lunak," *J. Apl. Tek. Sipil*, vol. 20, no. 2, pp. 131–138, 2022.

[17] S. S. Kandolkar and J. N. Mandal, "Behaviour of Reinforced Mine Waste Model Walls under Uniformly Distributed Loading," *Electron. J. Geotech. Eng.*, vol. 18, pp. 1351–1365, 2013.

[18] A. Waruwu, R. D. Sitinjak, and R. D. Susanti, "Potensi Nilai CBR Tanah Timbunan di Atas Tanah Gambut Dengan dan Tanpa Perkuatan," *Padur. J. Tek. Sipil Univ. Warmadewa*, vol. 10, no. 2, pp. 361–374, 2021.

[19] A. Waruwu, "Bamboo Reinforcement in Shallow Foundation on the Peat Soil," *J. Civ. Eng. Res.*, vol. 2014, no. 3A, pp. 96–102, 2014.

[20] A. Waruwu, R. D. Susanti, D. Endriani, and S. Hutagaol, "Effect of Loading Stage on Peat Compression and Deflection of Bamboo Grid with Concrete Pile," *Int. J. GEOMATE*, vol. 18, no. 66, pp. 150–155, 2020.

[21] A. Waruwu, H. Halim, T. Nasution, and Y. Hanova, "Bamboo Grid Reinforcement on Peat Soil under Repeated Loading," *J. Eng. Appl. Sci.*, vol. 13, no. 8, pp. 2190–2196, 2018.

[22] A. Waruwu, R. D. Susanti, N. Napitupulu, and J. O. Sihombing, "The Combination of Bamboo Grid and Concrete Pile as Soil Reinforcement under The Embankment," *Mag. Civ. Eng.*, vol. 106, no. 6, 2021.

[23] A. Waruwu, Maulana, and H. Halim, "Settlement Estimation of Peat Reinforced with Bamboo Grid under Embankment," *Int. Rev. Civ. Eng.*, vol. 8, no. 6, pp. 299–306, 2017.

[24] K. S. Akhil, N. Sankar, and S. Chandrakaran, "Behaviour of Bamboo Mat Reinforced Sand Beds under Different Density Conditions," in *Symposium on Recent Advances in Sustainable Geotechnics*, 2019.

[25] A. S. T. M. ASTM, "Standard Test Method for Bearing Capacity of Soil for Static Load and Spread Footings," *Am. Stand. Test. Methods*, no. D 1194-94, pp. 1–3, 1994.