Journal of Engineering and Applied Sciences 13 (8): 2190-2196, 2018
ISSN: 1816-949X

Bamboo Grid Reinforcement on Peat Soil under Repeated Loading

Aazokhi Waruwu, Husni Halim, Thamrin Nasution and Yudha Hanova
Department of Civil Engineering, Medan Institute of Technology, Medan, Indonesia

Abstract: Peat soils have the very low bearing capacity, high settlement and the low modulus of subgrade. The loads that will be received by subgrade are very varied like static and dynamic loads. To improve the behaviour of peat under repeated load, it is necessary to study the use of natural bamboo grids as reinforcement on peat soil. In this study, we will study the potential use of the bamboo grid in reducing the settlement, increase the modulus of subgrade, and increase the shear modulus. Testing was conducted with the laboratory study of the dynamic properties. The test result showed that, reinforcement of bamboo grid can increase the bearing capacity of peat soil. The number of layers of reinforcement effect on the settlement. A layer of the bamboo grid have not the significant influence on the reduction of settlement. Reinforcement of bamboo grid is effective on the number of reinforcement above two layers.

Key words: Peat, bamboo grid, repeated load, modulus of subgrade, shear modulus, grid

INTRODUCTION

Peat soils are classified as problematic soil, if it is used as a subgrade because of their low shear strength, high compressibility and permeability and consolidation settlement (Kallioglou *et al*., 2009). The loads that will be received by subgrade are very varied like static and dynamic loads. The dynamic loads are consist of earthquake load, vehicle load and machine load. Most regions in Indonesia are seismic hazard areas. Many structures have been built over peatland area. Foundation design on the peat soil is very important, especially in those locations where seismic activity is high like Indonesia.

The factors to be considered in the design of the construction are the behaviour of the ground during dynamic load. For consideration of subgrade structures, earthquakes are the important source of dynamic loading on peat soils. It is due to the damage potential of strong vibration and the fact that they represent an unpredictable and uncontrolled phenomenon in nature (Das, 1993).

Previous research about the dynamic properties of the peat were the dynamic tests on pipe piles in saturated peat (Crouse *et al*., 1993), investigated the dynamic properties of Sherman Island peat (Boulanger *et al*., 1998), the dynamic response of peat soil (Kramer, 2000), the shear modulus and damping ratio of organic soils, seismic response of peaty organic soils (Han and Danier, 2011), the compressive strength of remolded and undisturbed peat soil under cyclic loading (Tsushima *et al*., 2011), a full-scale model of model levee founded on peaty organic soil using eccentric mass shaker (Reinert *et al*., 2012), effect of fiber reinforcement on the stiffness and strength of peat (Hendry *et al*., 2014) and compressive behavior of peat due to theembankment with loading and unloading method (Waruwu *et al*., 2016, 2017; Waruwu and Maulana, 2017).

Peat soils are composed of a mixture of organic materials that are still in the process of decomposition respectively (Tsushima *et al*., 2011). Soil organic material such as peat are inherently variable and the results of laboratory studies involving a number of tests and the type of soil are not enough to determine the behaviour of complex materials appropriately. Kallioglou *et al*. (2009) state that the peat soils are types of soil with high organic content. Dynamic response of peat soil is not well understood but its poor competency is well known as an engineering material. Its use as a subgrade is generally avoided as the project location and replacement with more suitable materials but for thick peat soils have become problematic and another alternative is to use reinforcement.

Zidan (2012) states that study result in the static situation, the settlement of the foundation-geogrid system decreases significantly compared to the settlement occurring in the case of a dynamic load. The reinforced system seems to have the same tendency as observed in a static situation. Settlement of foundation varies linearly with the value of the amplitude of repeated load.

Bamboo is widely known as traditional sources for construction material and it grows in the tropical and sub-tropical regions of the world (Han and Danier, 2011). It is better than the geotextile. Soft clay soil that is reinforced by a combination of bamboo and geotextile as a separator between the soft soil and embankment

Corresponding Author: Aazokhi Waruwu, Department of Civil Engineering, Medan Institute of Technology, Medan, Indonesia

material, resulting in the end much better than reinforcement with geotextile, even from the high-tensile strength geotextiles. Marto and Othman stated that bamboo square pattern takes the load from backfill material and hence reduced the settlement much better compared to others. On the other hands, it formed an interlock to resist horizontal shear stress and increases the rigidity of bamboo. Other factors such as the bamboo cavity, where the trapped air inside the bamboo can gave the buoyancy effect and therefore distribute small embankment load to the soft soil layer.

Hegde and Sitharam (2014) use the bamboo grid and cells as the soft soil reinforcement and it is compared with geogrids and geocells. The bamboo material had advantages compared with geocells and geogrids, the bearing capacity of the soft clay reinforced with bamboo cell and grid was known higher than the geocells and geogrids. Bearing capacity of peat due under embankment load increased by 101-241% with the height of embankment above 13 cm than without embankment (Susanti *et al*., 2017). In addition to the increased bearing capacity of peat with preloading of loading-unloading method (Waruwu *et al*., 2017). Waruwu *et al*. (2016) state that result of the consolidation test with the loading-unloading method produces a larger settlement and faster process compared with other methods. It can accelerate and reduced the compression of peat. The embankment load can reduce the compressibility of peat. It can improve the compressive behaviour of peat soils. Figure 1 show that, the preloading with the loading-unloading method on peat soil considered capable speeding up the compressibility of peat soils (Waruwu *et al*., 2016).

The response of soil is controlled with shear modulus and damping ratio, it is key parameters to dynamic loading (Kallioglou *et al*., 2009). The small shear strain on the relationship of stress-strain is elastic linear, soil shear stiffness has its maximum value, $G = G_{max}$ and damping ratio its minimum value, $DT = Dt_{min}$. Value shear modulus, G based on the theory Borkan obtained by Eq. 1 (Prakash, 1981):

$$G = \frac{(1-\upsilon)C_z\sqrt{A}}{2.26} \quad (1)$$

$$C_z = \frac{q}{S_c} \quad (2)$$

Where:

C_z = In Eq. 2 can be obtained from relationship

q and S_c = The dynamic model of plate load test (Fig. 7)

Kallioglou *et al*. (2009) stated that the organic content exceeding 25% have a significant influence on

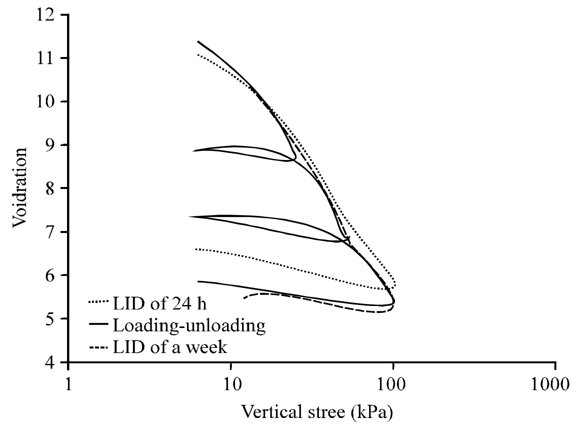

Fig. 1: Relationship between void ratio and log vertical stress (Waruwu *et al*., 2016)

G_{max} and DT_{min}. Fibrous peat contains high organic content and high fiber content. The results of the analysis showed that, the effect of fiber in peat soils depends on the initial stress (Hendry *et al*., 2014).

The shear modulus can be influenced by the frequency of load. Boulanger *et al*. (1998) stated that at higher loading frequency (1.0 Hz), the damping ratios are smaller than at under loading frequency (0.01 Hz). The difference between the damping ratios at a frequency of 1 and 0.01 Hz increased as the cyclic shear strain was increased.

The relationship between modulus reduction and damping of peat soil were roughly comparable to the recommended high plasticity clays (PI of 100-200). Secant shear moduli and damping are affected somewhat by loading frequency but they are not affected by the cyclic degradation (Boulanger *et al*., 1998). Likewise, peat tested showed a strong linear response similar to highly plastic clay (PI = 200%) (Kallioglou *et al*., 2009).

MATERIAL AND METHODS

Test material under study was taken from the peat soils of Riau. The test results show that, the physical properties of peat samples have Water content (W_c) of 945.18%, bulk density (γ_b) of 10.74 kN/m^3, organic content (O_c) of 95.94%, fiber content (F_c) of 27.92% and ash content (A_c) of 4.06%.

Modelling was done in the laboratory by using the peat specimens that entered and compacted in the box with the width (L) of 90 cm, the length of 110 cm and a height of 90 cm (Fig. 2). Plate load test and measuring of settlement can be seen in Fig. 3. Peat was compacted by approaching the field density and water content (Waruwu *et al*., 2016, 2017; Waruwu and Maulana,

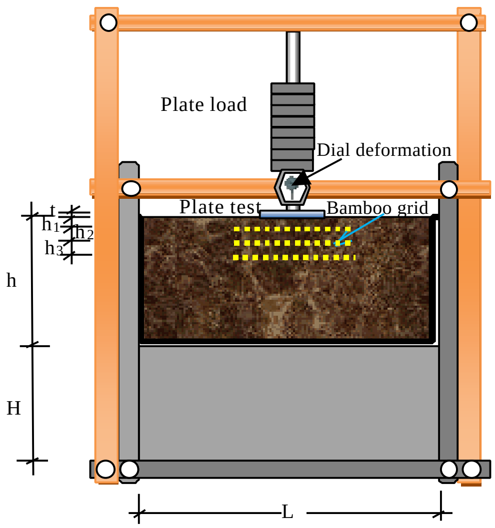

Fig. 2: Testing scheme in the laboratory

Fig. 3: Plate load test

2017). The peat thickness was (h) of 50 cm and a thick layer of hard soil (H) of 40 cm. A form of plates load test was a circle with (d) of 10 and 20 cm and thick (t) of 5 mm.

Model testing was done without and with a reinforcement of bamboo grid with widths of 26, 30 and 34 cm for a plate diameter of 10, 15 and 20 cm respectively (Fig. 4). The Bamboo grid was placed 5 cm (h_1) of the base plate test and every 5 cm ($h_2 = h_3$) to the next tier up to three layers. Model loading was applied with a load of steel plates. Loading system used repeated load by loading-unloading method (Waruwu *et al.*, 2016, 2017b).

The increase was then performed if the settlement had reached 0.03 mm/min, a settlement in dial gauge readings every 1 min. For loading, the addition of up to 6 times and then the load was unloading to the first load. Each loading was done reading dial deformation in the same way. Loading-unloading cycles continued until 5 times.

Fig. 4: Bamboo grid as reinforcement

RESULTS AND DISCUSSION

Results of the study consisted of the repeated load test on peat unreinforced and with reinforcement of bamboo grid. Based on these data will be discussed the influence of bamboo grid in reducing the settlement, increasing the modulus of subgrade and increasing the shear modulus.

Result of repeated load test on peat: the results of plate loading test for diameter 10 cm on peat unreinforced and with reinforcement of bamboo grid can be seen in Fig. 5. Reinforcement effect on the settlement of peat soil. The settlement that occurred in the peat with reinforced of the bamboo grid is smaller than unreinforced.

The pattern of relationships settlement and pressure on peat with reinforced slighter than peat unreinforced. It shows that, the compression of peat decrease due to the reinforcement of bamboo grid. Figure 6 shows the settlement in peat soil with different density, the settlement of peat that dense was found smaller than that it not dense under the repeated load.

Effect of bamboo grid reinforcement to settlement: the settlement that occurred during the addition of the load on the plate diameter of 10 cm can be seen in Fig. 7. Peat with bamboo grid reinforcement provides the settlement are smaller than the peat unreinforced. Reinforcement of bamboo grid can increase the bearing capacity of peat soil. The number of layers of reinforcement effect on the settlement. A layer of the bamboo grid has not the significant influence on the reduction of settlement. Reinforcement of bamboo grid is effective on the number of reinforcement above two layers. It is shown that using of three layers of the

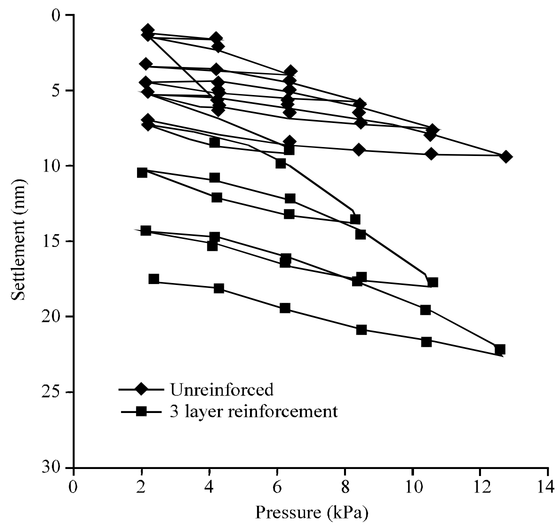

Fig. 5: Results of the plate load test due to repeated load for plate with diameter of 10 cm

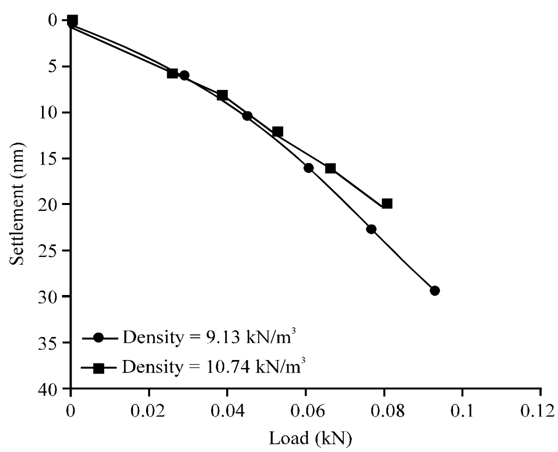

Fig. 6: Relationship between load and settlement in the different density

bamboo grid is better than a and two layer. For further testing, conducted by three layers of reinforcement for plate diameter of 10, 15 and 20 cm (Fig. 8-10). Reinforcement of three layers of the bamboo grid has a significant influence on the settlement of peat soil. The three types of tests are performed, they provide a reduction settlement quite good.

In Table 1 shows the reduction in settlement due to the reinforcement on a plate of the diameter of 10, 15 and 20 cm. In the third type of testing, settlement of the peat reinforced with three layers of bamboo grids can reduce the settlement of 56.49, 62.51 and 80.28% for the plate diameter of 10, 15 and 20 cm, respectively. Plate size reduction effect on the settlement. Large-size plates provide greater reduction in the settlement.

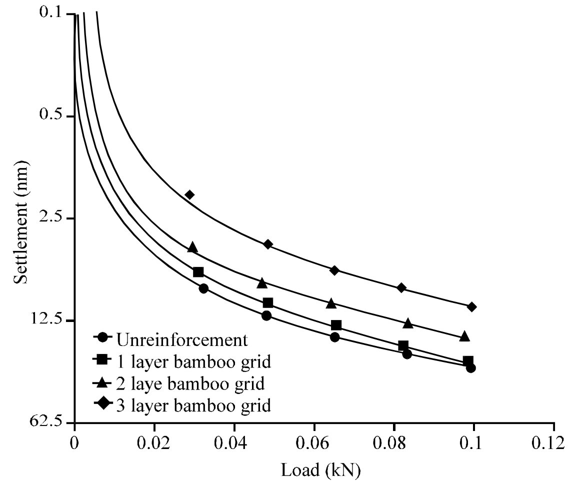

Fig. 7: Relationships between the load and settlement due to reinforcement of bamboo grid

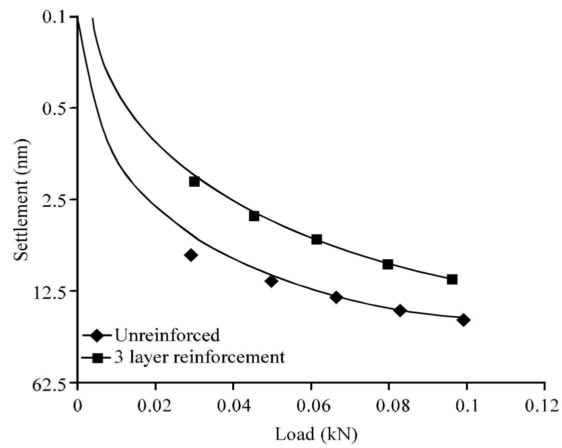

Fig. 8: Settlement due to the reinforcement of the three-layer of bamboo grid on plate with a diameter of 10 cm

Effect of bamboo grid reinforcement to modulus of subgrade: from the relationship between the settlement and pressure (q = load/area) on the loading-unloading test can be determined elastic settlement. It is the difference in the settlement at the time of loading and unloading. For example taken the results of test plate size of 15 cm unreinforced (Fig. 11). Based on the elastic settlement value and the pressure from Fig. 11 can be described relationships between the pressure (q) and elastic Settlement (S_e) as shown in Fig. 12. From q/s_e may be determined the average modulus of subgrade value (C_z) and the result as Table 2 and Fig. 13. Installation of three-layer of bamboo grids can increase the modulus of subgrade. Diameter larger plates produce modulus of

Table 1: Effect of bamboo grid to the settlement

Load (kN)	Settlement. S (mm) Unreinforced (cm) 10	15	20	Three layers of reinforcement (cm) 10	15	20	Reduction settlement to plate unreinforced (%, cm) 10	15	20
0.03	6.040	7.600	5.980	1.70	2.16	0.97	71.85	71.58	83.78
0.05	9.210	10.41	9.210	3.90	4.01	1.64	57.65	61.48	82.19
0.07	12.10	13.91	12.10	5.73	5.33	2.39	52.64	61.68	80.25
0.08	15.24	16.94	15.24	7.50	6.75	3.49	50.79	60.15	77.10
0.10	18.24	19.53	18.24	9.21	8.27	4.00	49.65	57.65	78.07

Table 2: Effect of bamboo grid to the modulus of subgrade

Diameter of plate (cm)	Modulus of subgrade C_z (kN/m^3) Unreinforced	Three layers of reinforcement	Improvement the modulus of subgrade (%)
10	2173.90	3324.20	52.91
15	1121.50	2286.40	103.87
20	532.88	2118.20	297.50

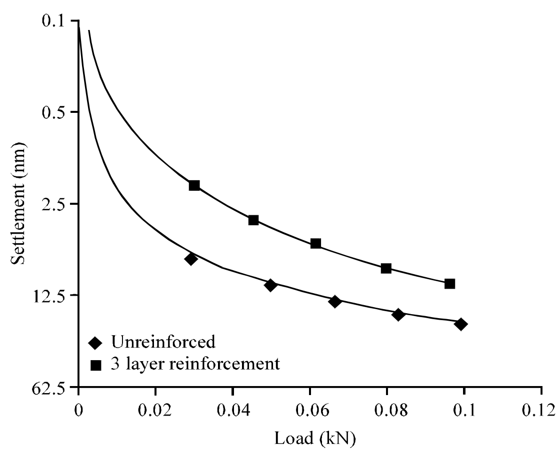

Fig. 9: Settlement due to the reinforcement of the three-layer of bamboo grid on plate with a diameter of 15 cm

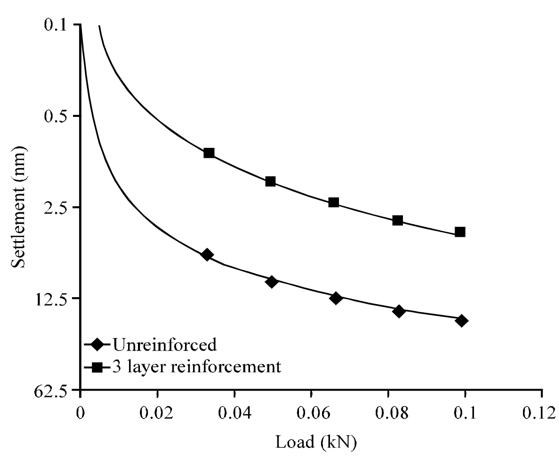

Fig. 10: Settlement due to the reinforcement of the three-layer of bamboo grid on plate with a diameter of 20 cm

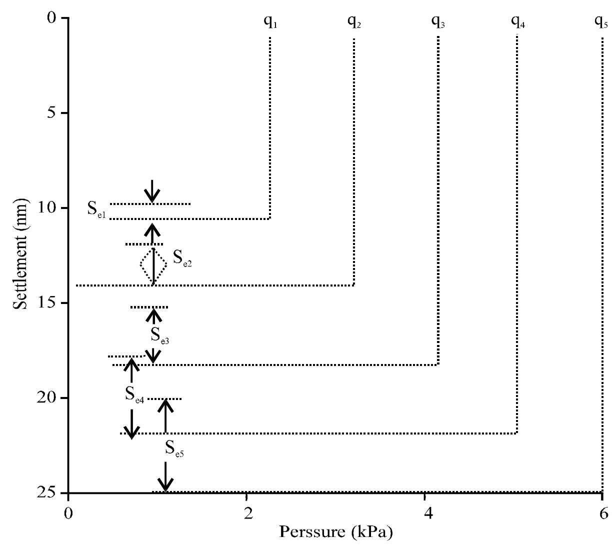

Fig. 11: Relationship between the pressure and settlement in plate diameter of 15 cm

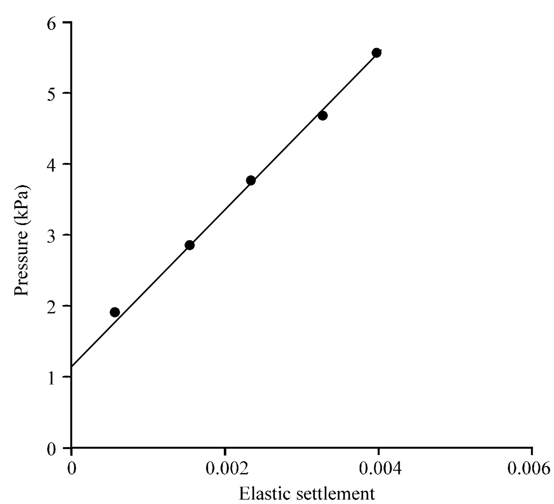

Fig. 12: Relationship between the pressure and elastic settlement in plate diameter of 15 cm

subgrade greater than smaller diameter plate. Improved modulus of subgrade is 34.60, 50.95 and 74.84% for a plate diameter of 10, 15 and 20 cm, respectively. Shear strength parameters of peat showed that, the of cohesion (c)

Table 3: Effect of bamboo grid to the shear modulus

Diameter of plate (cm)	Shear Modulus G (kPa) Unreinforced	Three layers of reinforcement	Improvement the shear modulus (%)
10	58.70	89.77	52.91
15	45.42	92.61	103.87
20	28.78	114.40	297.50

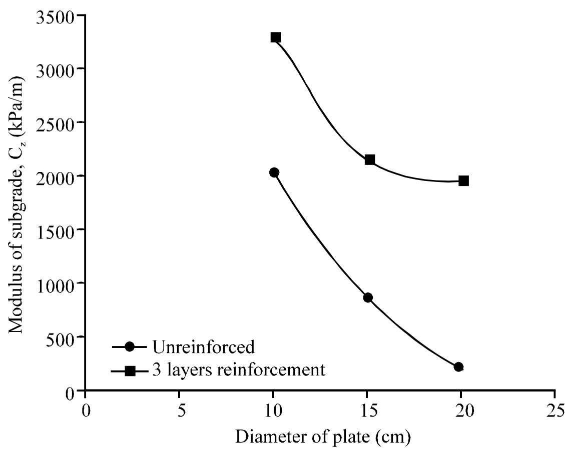

Fig. 13: Improvement of modulus subgrade due to reinforcement

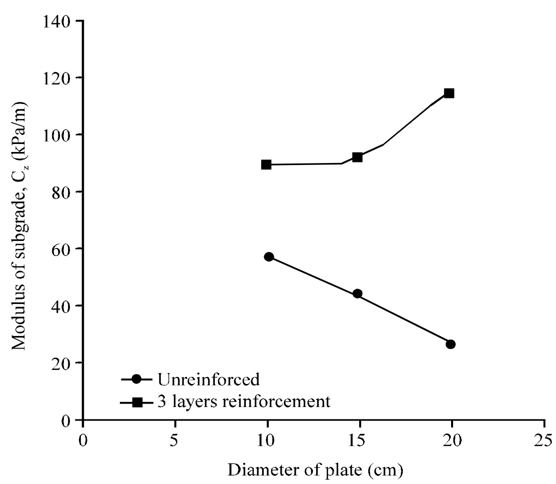

Fig. 14: Improvement of shear modulus due to reinforcement

2.8 kPa and angle of internal friction (φ) 33.22°. The coefficient of lateral earth pressure, k_o = 1-sin φ = 0.452, Poisson ratio = $k_o/(1+k_o)$ = 0.311. By using the Eq. (1) then obtained an increase in shear modulus (G) as shown in Table 3 and Fig. 14. The increase in modulus of subgrade nearly constant in diameter of the plate above 15 cm (Fig. 13). While the G values are higher for the diameter of large plate and increasingly significant at above 15 cm of diameter.

Reinforced of bamboo grid able to increase the modulus of subgrade and shear modulus of soil. These parameters are important to know for the design of construction above subgrade of peat under the dynamic loads. Thus, the using bamboo grid capable reducing failures of construction under dynamic loads.

CONCLUSION

The density of peat effect the rate settlement, the settlement of peat that dense was found smaller than that it not dense under the repeated load. Reinforcement of bamboo grid can increase the bearing capacity of peat soil. The number of layers of reinforcement effect on the settlement. A layer of the bamboo grid has not the significant influence on the reduction of settlement. Reinforcement of bamboo grid is effective on the number of reinforcement above two layers. It show that using of three layers of the bamboo grid is better than a and two layer.

Settlement of the peat reinforced with three layers of bamboo grids can reduce the settlement of 56.49, 62.51, and 80.28% for the plate diameter of 10, 15and 20 cm, respectively. The modulus of subgrade and shear modulus of peat soil increased by 52.91, 103.87 and 297.50% in the presence of three layers of the bamboo grid for the plate diameter of 10, 15 and 20 cm, respectively. The increase in modulus of subgrade nearly constant in diameter of the plate above 15 cm. While the G values are higher for the larger diameter of the plate and increasingly significant at above 15 cm of diameter.

Reinforced of bamboo grid able to increase the modulus of subgrade and shear modulus of soil. These parameters are important for the design of construction above subgrade of peat under the dynamic loads. Thus, the using bamboo grid capable reducing failures of construction due to dynamic loads. Reinforcement of three layers of the bamboo grid can reduce settlement, increasing the modulus of subgrade and shear modulus significantly.

ACKNOWLEDGEMENTS

The research would like to thank the Ministry of research, Technology and Higher Education of the Republic of Indonesia for supporting this research with Grant No. of 001/K1.1/LT/2016.

REFERENCES

Boulanger, R.W., R. Arulnathan, L.F. Harder Jr, R.A. Torres and M.W. Driller, 1998. Dynamic properties of Sherman Island Peat. J. Geotech. Geoenviron. Eng., 124: 12-20.

Crouse, C.B., S.L. Kramer, R. Mitchell and B. Hushmand, 1993. Dynamic tests of pipe pile in saturated peat. J. Geotech. Eng., 119: 1550-1567.

Das, B.M., 1993. Principles of Soil Dynamics. PWS-Kent Publishing Company, Boston, Massachusetts, ISBN:9780534931292, Pages: 570.

Han, J. and E.A. Daniel, 2011. Seismic Response of Peaty Organic Soils as a Levee Foundation Material. In: Geo-Frontiers 2011: Advances in Geotechnical Engineering, Moss, R.E. and J.C. Hollenback, (Eds.). American Society of Civil Engineers, Reston, Virginia, USA., ISBN:9780784476543, pp: 3097-3106.

Hegde, A. and T.G. Sitharam, 2014. Use of bamboo in soft-ground engineering and its performance comparison with geosynthetics: Experimental studies. J. Mater. Civil Eng., 27: 1-9.

Hendry, M.T., S.L. Barbour and C.D. Martin, 2014. Evaluating the effect of fiber reinforcement on the anisotropic undrained stiffness and strength of peat. J. Geotech. Geoenviron. Eng., 140: 1-11.

Kallioglou, P., T. Tika, G. Koninis and K. Pitilakis, 2009. Shear modulus and damping ratio of organic soils. Geotech. Geol. Eng., 27: 217-235.

Kramer, S.L., 2000. Dynamic response of mercer slough peat. J. Geotech. Geoenviron. Eng., 126: 504-510.

Prakash, S., 1981. Soil Dynamics. McGraw-Hill, New York, USA., ISBN:9780070506589, Pages: 426.

Reinert, E.T., S.J. Brandenberg, J.P. Stewart and R.E. Moss, 2012. Dynamic field fest of a model levee founded on peaty organic soil using an eccentric mass shaker. Proceedings of the World Conferences on Earthquake Engineering (WCEE), September 24, 2012, University of California, Oakland, California, pp: 1-10.

Susanti, R.D., Maulana and A. Waruwu, 2017. Bearing capacity improvement of peat soil by preloading. ARPN. J. Eng. Appl. Sci., 12: 121-124.

Tsushima, M., H. Oikawa and J. Komatsu, 2011. Unconfined compressive strength characteristics of remolded and undisturbed peat consolidated under cyclic loading. Proceedings of the 21th International Conference on Offshore and Polar Engineering, June, 19-24, 2011, International Society of Offshore and Polar Engineers, Mountain View, California, pp: 1-19.

Waruwu, A. and H.H. Maulana, 2017. Settlement estimation of peat reinforced with bamboo grid under embankment. Intl. Rev. Civil Eng., 8: 299-306.

Waruwu, A., C.H. Hardiyatmo and A. Rifa'i, 2017. Deflection behavior of the nailed slab system-supported embankment on peat soil. J. Appl. Eng. Sci., 15: 556-563.

Waruwu, A., H.C. Hardiyatmo and Rifa'i, 2016. A compressive behavior of bagansiapiapi-riau peat in Indonesia. Electron. J. Geochnical Eng., 21: 5217-5227.

Zidan, A.F., 2012. Numerical study of behavior of circular footing on geogrid-reinforced sand under static and dynamic loading. Geotech. Geol. Eng., 30: 499-510.