VOL. 10, NO. 8, MAY 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

MODEL TEST OF ROAD EMBANKMENT REINFORCED BY INCLINED PILE ON SOFT SOIL

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ABSTRACT

Indonesia is covered by wide lowland area which is dominated by soft clay. Particularly, East Kalimantan has specific conditions where soft clay is found contaminated with coal. Road construction on soft soil faces several problems therefore a various stabilizing method need to apply in the site since the soft soil has particular characteristic. The local trees (Melalucea Lencadendron Linn/Galam) are easily found in Kalimantan and have long life if buried in the swamp. This timber (Galam) is considered can be used as an alternative material for soil reinforcement. In this study, full scale test was conducted to observe the effectiveness of micropile (Galam timber) in reducing the settlement and compared to various condition (i.e. geotextile reinforcement and without reinforcement). During the construction stage of preloading, the settlement monitored by using a settlement plates, lateral displacement monitored by inclinometers and pore water pressure monitored by piezomenters. Measurements were taken every day for each embankment construction stage (3 months). A numerical modeling was conducted in this study in order to validate the full scale test result. The result shows that the micropile that driven with the slope of 15 degree found the value of settlement is 400cm. The micropile distributes the surcharge load to the pile and decrease the differential settlement. Good agreement of numerical modeling compared to full-scale test result also found in this study.

Keywords: timber pile, soft soil, soil improvement, settlement, inclined pile.

INTRODUCTION

The problem of construction on soft clay is the low bearing capacity and differential settlement, therefore innovation in soil improvement is needed.

Recently, many researchers conducted field observation of full-scale model (e.g. Falorca *et al*., 2011; Won and Kim, 2007; Hatami and Bathurst, 2005, 2006; Bergado *et al*., 1995, 2000, 2003; Ling and Leshchinsky, 2003; Varuso *et al*., 2005). Nunes *et al*. (2013) reported that the settlement efficacy of pile-supported embankment is a reliable parameter to assess the overall performance of the rigid inclusion technique.

Due to the limitations of construction materials especially in East Kalimantan, most of the construction materials for road construction were imported from outside the Kalimantan Island causing a very high costs construction. Moreover, the local trees (melalucea lencadendron linn/galam) are easily found in Kalimantan and have long life if buried in the swamp. This timber (galam) is considered can be used as an alternative material for soil reinforcement over a soft clay.

This study present an experiment full-scale trial embankment constructed on soft soil (contaminated with coal) reinforced by several reinforcement method. The performance of inclined pile compared to construction of conventional pile and geotextile reinforcement was observed. A numerical modeling also conducted in this study to validate the full scale test result.

MATERIAL PROPERTIES

Soil layer properties

The soil samples were collected from the borehole at the site. The general soil properties consist of very soft clay over the top 18 m. The silty sand is found between the depths of 18 and 30 m. This layer is underlain by medium stiff clay down to about 70 m depth. The subsoil profile is shown in Figure-1. Soil samples were collected from the borehole at the site. The engineering properties were obtained by performing index properties and consolidation test. The subsoil properties are presented in table 1.

Timber pile properties

The properties of timber (galam) which is used as a pile are presented in Table-2.

Table-1. Soil properties.

Soil Type	Layer 1 (0,00 - 4,00) m	Layer 2 (4,00 - 6,00) m	Layer 3 (6,00 - 12,00) m	Layer 4 (12,00 - 18,00) m	Layer 5 (18,00 - 25,00) m	Layer 6 (25,00 - 30,00) m	Fill
	Soft Clay					Sand	Slected Sand and Gravel
γ_{unsat} [kN/m³]	12	12	13	15	16	16.5	19
γ_{sat} [kN/m³]	14.5	14.5	15	16	18	20	20
k_x [m/day]	6.89E-04	6.89E-04	6.89E-04	6.89E-04	6.89E-04	2	2
k_y [m/day]	1.38E-03	1.38E-03	1.38E-03	1.38E-03	1.38E-03	1	1
E [kN/m²]	-	-	-	-	-	8000	10000
v [-]	-	-	-	-	-	0.35	0.35
Cc [kN/m²]	0.9	0.9	0.85	0.6	0.4	-	-
Cs [kN/m²]	0.13	0.11	0.13	0.09	0.09	-	-
e_0 [-]	2.2	2.2	2	1.8	1.5	-	-
φ [°]	5	8	12	14	16.5	30	33
c [kN/m²]	10	12	20	25	30	1	1

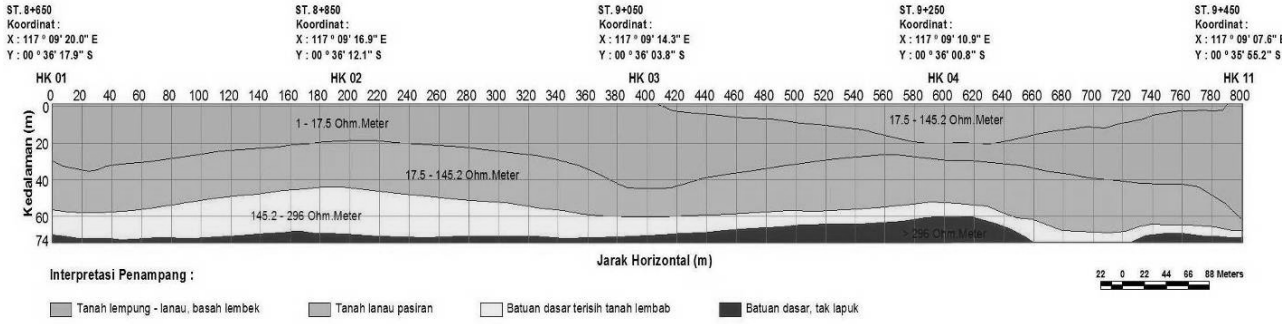

Figure-1. Soil profile.

Table-2. Characteristic of timber (galam).

Characteristic of Galam	Value
Water content	22,95%
Compressive strength //	23,3 Mpa
Compressive strength ⊥	14,4 Mpa
Tensile strength	17,9 Mpa
Bending strength	101,4 Mpa

EMBANKMENT CONSTRUCTION

A Full-scale test was carried out in East Kalimantan, Indonesia and constructed on 16.5 m width and 20 length of each type of reinforcement with 4,5 m of embankment high. A typical cross section showing soft soil, piles and geotextile is shown schematically in Figure-2. The piles were installed with 6 m length and beneath the embankment a layer of geotextile was placed. The arrangement of pile reinforcement is shown in Figure-3.

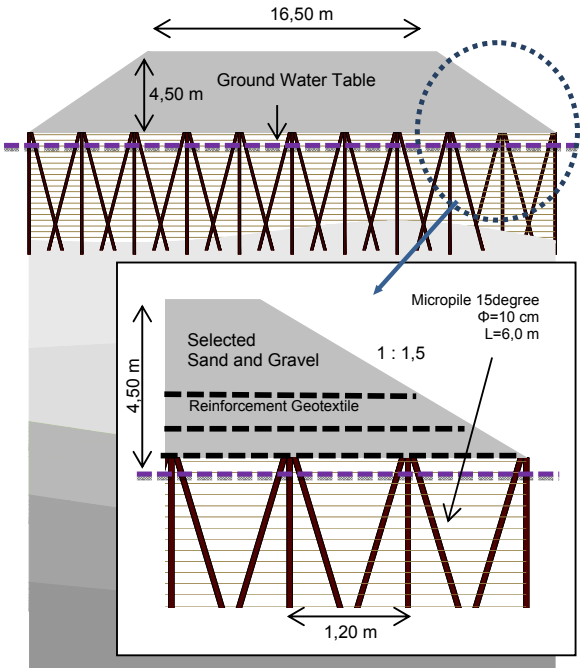

Figure-2. Typical cross section.

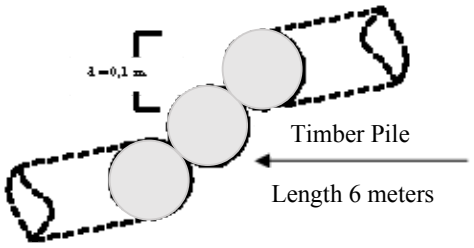

Figure-3. Arrangement of inclined pile reinforcement.

Instrumentation

Since the embankment was constructed on highly compressible soil, several instruments were installed on the embankment such as settlement plate, inclinometer and piezometer. The instrumentation in the subsoil for each type of reinforcement {i.e. geotextile, conventional and inclined pile} was installed prior to the construction of the embankment as shown in Figure 4, 5 and 6.

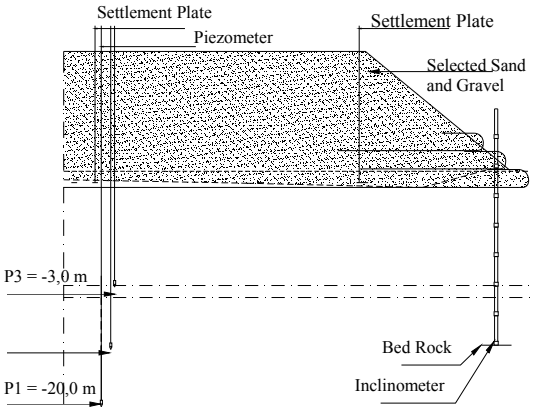

Figure-4. Geotextile reinforcement.

RESULTS AND DISCUSSIONS

Observation of trial embankment construction conducted for 3 months. According to the piezometer results, the pore water pressure increases with the increasing of depth. There is no significant change of the amount of pore water pressure among the types of reinforcement as shown in Figure-7. Based on the observation results of settlement, the settlement of geotextile reinforcement was found about 1, 1 m. It is indicated that the geotextile reinforcement inadequate in supporting the trial embankment with 4, 5 m height. The bearing capacity also very low which is indicated with the huge amount of lateral displacement observed in the field.
Settlements were measured by precise leveling control with reference to a fix benchmark. The lateral movement of the soil and embankments were measured by using a digital inclinometer which is installed vertically at the edge of embankment. Digital piezometer was installed near the settlement plate.

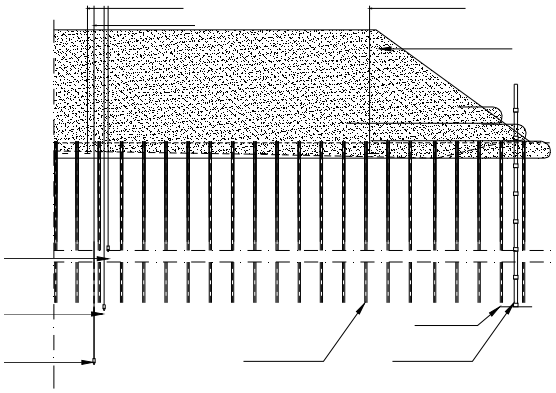

Figure-5. Conventional pile reinforcement.

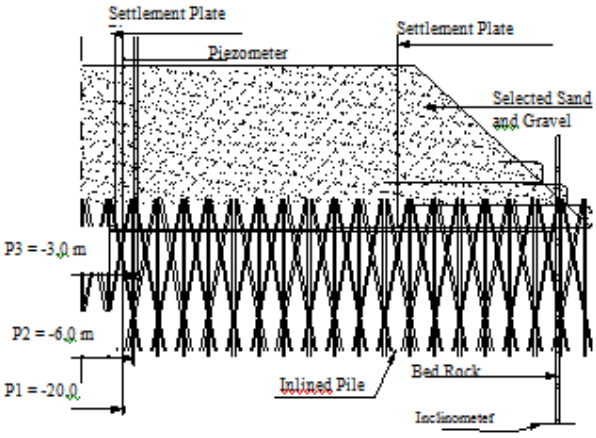

Figure-6. Inclined pile reinforcement.

For conventional pile reinforcement, the settlement was found lower than geotextile reinforcement. The total settlement reduces about 52%. It is indicated that the presence of piles tend to increase the bearing capacity of subsoil in supporting the embankment.

Similar result obtained with the inclined pile reinforcement method. Reduction of settlement was found around 65% compare to geotextile reinforcement. The bearing capacity of this type of reinforcement has a highest value compare to other reinforcement method. The result of total settlement (3 months) are shown in Figure-8 and summarized in Table-3.

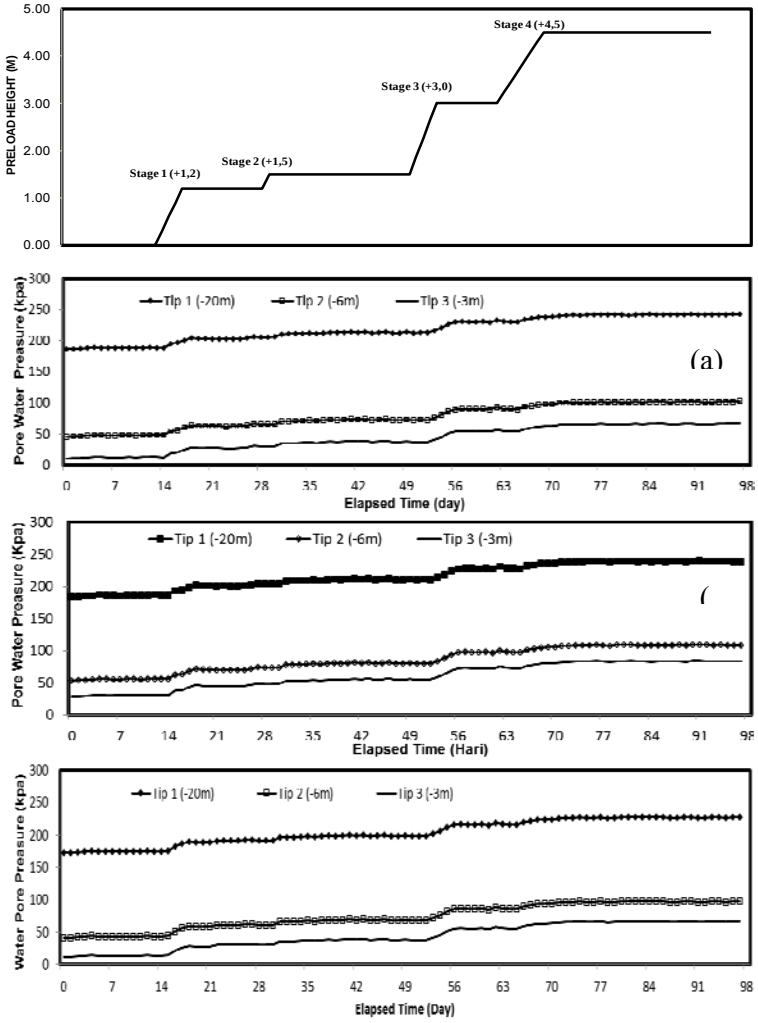

Figure-7. Piezometer result geotextile reinforcement conventional pile reinforcement inclined pile reinforcement.

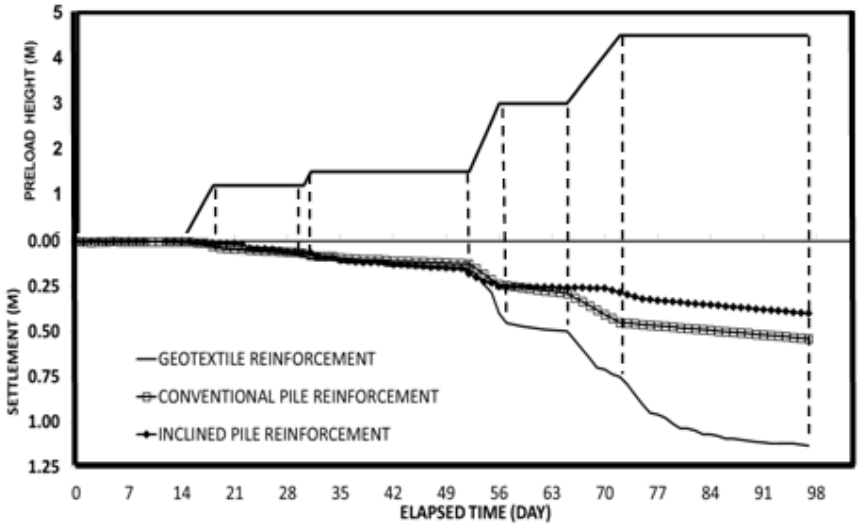

Figure-8. Summary of time versus settlement observations of inclined pile reinforcement.

Numerical modeling was conducted to analyze the settlement behavior reinforcement of micropile with 15° inclination on soft soil deposit after preloading. The effectiveness of the micropile 15° to reduce the settlement can be known by compared the method with geotextile reinforcement and reinforcement with micropile. Analysis was carried out until 120 days of road embankment construction with a total settlement for road embankment construction with reinforcement micropile 15° is found 0.47 m. Construction of road embankment with geotextile reinforcement obtained predicted settlement by 1.25 m. Deformation pattern of geotextile reinforcement embankment construction. Construction of road embankment of micropile reinforcement with a distance of 1.0 meters predicted a settlement of 0.60 m. Numerical analysis shows the construction of a micropile 15° type with a length of 6 meters can reduce the settlement about 60 % with a distance of 1.20 meter installation when compared with geotextile reinforcement. While micropile type with a length of 6 meters can reduce the settlement until > 50 % with a distance of 1.00 meter installation when compared with geotextiles reinforcement. The results of full scale test (filed observation) and numerical modeling results are shown in Figure-9. The comparison result shown that the result for both methods is quite similar (Figure-10).

Table-3. Result of settlement plate observation.

No.	Construction type	Settlement (cm)	Reduction of settlement compare to geotextile reinforcement (%)
1	Geotextile	113	-
2	Conventional Pile	54	52
3	Inclined Pile	40	65

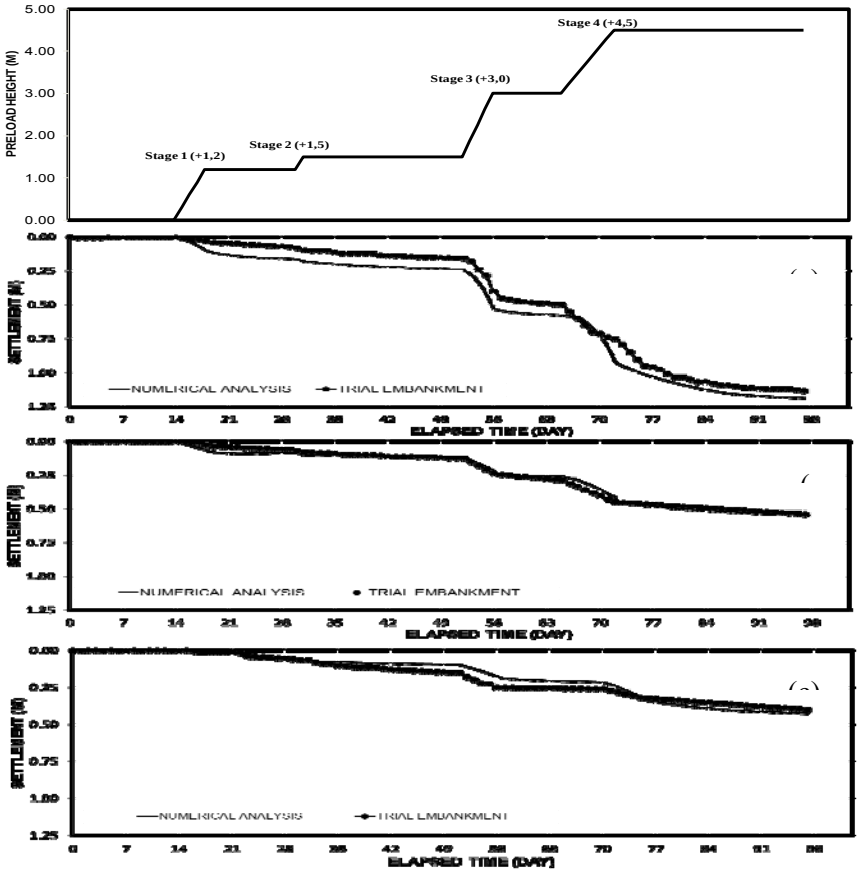

Figure-9. Field observation and numerical analysis of settlement
a) Geotextile Reinforcement
b) Conventional Pile Reinforcement
c) Inclined Pile Reinforcement

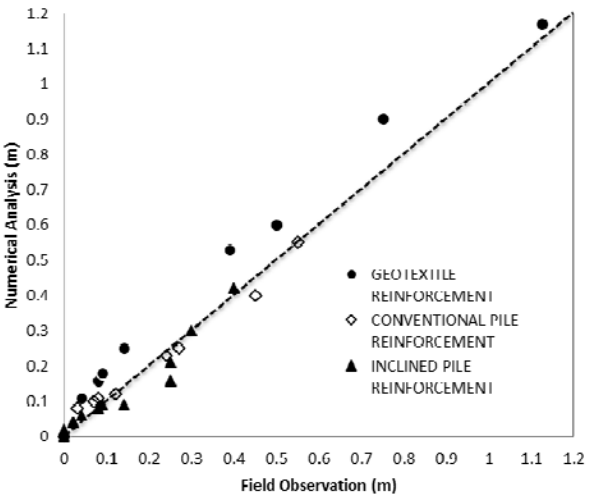

Figure-10. Result comparison between field observation and numerical analysis.

CONCLUSIONS

The bearing capacity of reinforced soil with conventional and inclined pile are sufficient to support the trial embankment (4, 5 m). The small amount of lateral movement was observed for both pile reinforcement which is indicated that the sufficient slope stability of trial embankment occur with the installation of pile reinforcement. The total settlement reduction for both conventional and inclined pile compared to geotextile reinforcement was found 52% and 65% respectively. Therefore, the inclined pile reinforcement has a potential application for road construction on soft soil as an alternative construction method. Good agreement of numerical modeling compared to full-scale test result also found in this study.

REFERENCES

Bergado D.T., Chai J.C., Miura N. 1995. FE analysis of grid reinforced embankment system on soft Bangkok clay. Computers and Geotechnics. 17: 447-471.

Bergado D.T., Teerawattanasuk C., Youwai S., Voottipruex P. 2000. FE modelling of hexagonal wire reinforced embankment on soft clay. Canadian Geotechnical Journal. 37(6): 1-18.

Bergado D.T., Youwai S., Teerawattanasuk C., Teerawattanasuk C., Visudmedanukul P. 2003. The interaction mechanism and behaviour of hexagonal wire mesh reinforced embankment with silty sand backfill on soft clay. Computers and Geotechnics. 30: 517-534.

Falorca I., Gomes L. and Pinto M. 2011. A full-scale trial embankment construction with soil reinforced with short randomly distributed polypropylene microfibers. Geosynthetics International. 18(5): 280.

Hatami K., Bathurst R.J. 2005. Development and verivication of a numerical model for the analysis of geosynthetic-reinforced soil segmental walls under working stress conditions. Canadian Geotechnical Journal. 42: 1066-1085.

Hatami K., Bathurst R.J. 2006. Numerical model for reinforced soil segmental walls under surcharge loading. Journal of Geotechnical and Geoenviromental Engineering, ASCE. 136(6): 673-684.

Ling H.I., Leshchinsky D. 2003. Finite element parametric study of the behaviour of segmental block reinforced – soil retaining walls. Geosynthetics International. 10(3): 77-94.

Nunez M. A., Briancon L. and Dias D. 2013. Analyses of a pile-supported embankment over soft clay: Full- scale experiment, analytical ans numerical approaches. Engineering Geology. 153: 53-67.

Varuso R.J., Grieshaber J.B., Nataraj M.S. 2005. Geosynthetic reinforced levee test section on soft normally consolidated clay. Geotextiles and Geomembranes. 23(4): 362-383.

Won M.S., Kim Y.S. 2007. Internal deformation behaviour of geosynthetics-reinforced soil walls. Geotextile and Geomembranes. 25(1): 10-22.