Vacuum Preloading Consolidation Settlement Analysis with Two Dimentional Finite Element Method

Andreas Erdian Wijaya, Paulus Pramono Rahardjo

Abstract—Big city and urban settlement are widely found near port and located around shore. This will generate a lot of Young sediment soil which usally unfavorable for construction. The application of preloading to induce a settlement before construction and increase bearing capacity of soil foundation is a common practice. Preloading is usually done by pressure the insitu soil with a backfill of soil/sand/gravel, this create another problem during construction, such as low bearing capacity of sub surface soil could lead into land slide. Vacuum Preloading is one of most popular soil improvement technique for dealing with soft soil that require high operational load. Vacuum Preloading or Vacuum Consolidation Method is applied by creating a vacuum condition underneath ground with the help of prefabricated vertical drain and air-tight sheet. Practically by engineering atmospheric pressuce, vacuum preloading could provide preloading pressure from 40 to 90kPa depent on the whole vacuum system efficiency. Conventional consolidation analysis that currently available for predictiong consolidation settlement is not realiable, hence the urge to better anticipate settlement and understand soil behavior due to vacuum preloading is necessary. Finite Element Method is found as a solution for this problem, by manipute the pressure head inside line element we could modeled pressure create by vacuum preloading and appropriately obtain reliable prediction of soil settlement and soil behavior under tension/suction.

Index Terms— Consolidation Analysis, Finite Element Model, Ground Improvement, Soft Soil Engineering, Soil Improvement, Vacuum Consolidation, Vacuum Preloading.

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1 Introduction

SOIL improvement or ground improvement is one of construction phase that perfume to optimize sub soil condition. Soil improvement method for soft clay treatment is usually perform with consolidation approach. Consolidation process could be induced by preload the whole construction area with a temporary load that later will be replace by permanent construction. Preloading will increase the bearing capacity of foundation soil and reduce/elimintate post settlement. Most common and simple ground improvement method is by soil preloading. Soil preloading perform by backfilling the whole construction area with soil and usually accelerate by using prefabricated vertical drain (PVD). Biggest problem when using preloading method is the improvement time. Since permeability of clay is very low, the improvement with consolidation process could take month to years to finish. To shorten the drainage length of water and reduce the consolidation duration PVD is installed to the ground. PVD usually installed with spacing of 1m, so rather than flow to the surface, water could flow out from the soil mass radially into the PVD.

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Numerous projects have been succefully constructed in a soft soil with vacuum preloading method. Since the method produce difference settlement behavior compare with the traditional consolidation settlement analysis, this paper intended to model the settlement phenomenon with a numerical approach using finite elemenet method.

2 Project Overviews

Construction of new airport in Bangkok, Thailand, full-scale test embankment was constructed on the soft clay at the site to learn about the effect of PVD to the consolidation time. PVD will accelerate the consolidation and excess pore water pressure dissipation due to backfill with conventional preloading.

This study will be focus on portions of case history that have been well publish and make a comparation between the result from soil preloading model and improvement with vacuum preloading. The result of the field tests has been studied and analyzed by two different research group from Asian Institute of Technology in Thailand and the other group from Wallongong University in Australia. The finding is presented in two papers listed in the reference section below.

3 Numerical Model

This study will focus on analysis of one of trial embankment with PVD spacing 1.5m and PVD installed to depth 12m. embankment were constructed to height 4.2m with 3H:1V sloping. The width of embakment were approximately 40x40m. Project Area is a wet area with 10m soft soil under 2m of surficial crust. Soft soil layer follows by stiff clay until 20m depth. For this study subsoil will divided into three layer and stiff clay layer is consider have a very low compressibility, hence could be ignore. Soil layer and its parameter could be found in following table and figure.

TABLE 1
Soil Properties

layer	γ	Lamda	Kappa	e0	OCR	c'	ϕ'	E [kPa]	v'
Weathered clay	16.0							10000	0.334
very soft clay	14.0	0.900	0.180	2.75	1.50		23.1		0.334
soft clay	15.0	0.500	0.100	2.70	1.50		25.4		0.334

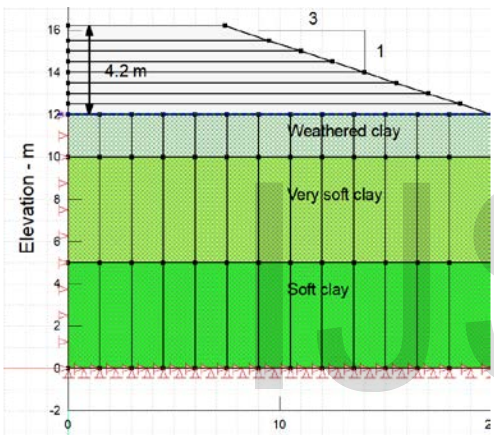

Fig. 1. Soil Stratification and Finite Element Model.

Soft soil was modeled with modified cam-clay constitutive relationship. The weathered surficial clay is over-consolidated and consequently is acceptable to modeled using linear elastic.

4 Soil Preloading Model

PVD model using help of hydraulic boundary condition. Based on the soil investigation data, ground water table is located at surface of insitu soil (located at elevation 12 on the model). PVD will be modeled as a hydraulic boundary condition with head along the boundary element is equal to the head of hydrostatic water pressure, in other word the total water head inside the hydraulic boundary element is defined as 12.

For the load of soil preloading, the backfilling rate was modeled according to the site notes. Duration of backfill could be found in following figure. Upon loading, excess pore water pressure will generate on the soil mass and become higher than hydrostatic condition. Since along PVD boundary element is defined with a hydrostatic pressure, the water will flow into the PVD and dissipate.

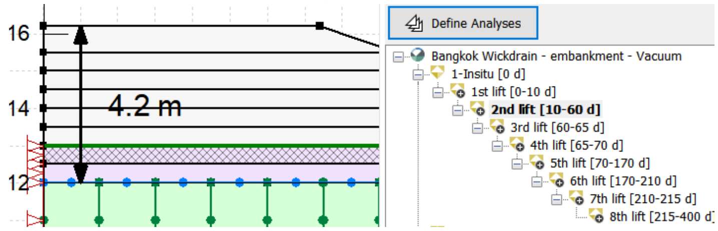

Fig. 2. Backfilling Rate

5 Vacuum Preloading Model

Vacuum Preloadig is modeled using hydraulic boundary element like soil preloading, but the water pressure head is defined as 7.5m below hydrostatic pressure. by doing so, under no additional backfill, the water will dissipate and flow into the boundary element due to the difference of pressure around 75kPa (7.5m equivalent water column). the pressure is assuming to be 75kPa in order to match the soil preloading load of 4.2m with unit weight 18kN/m³. In reality vacuum pressure could vary from 40kPa to 90kPa. vacuum pressure efficiency is highly depent on the site condition, sealing method and soil stratification.

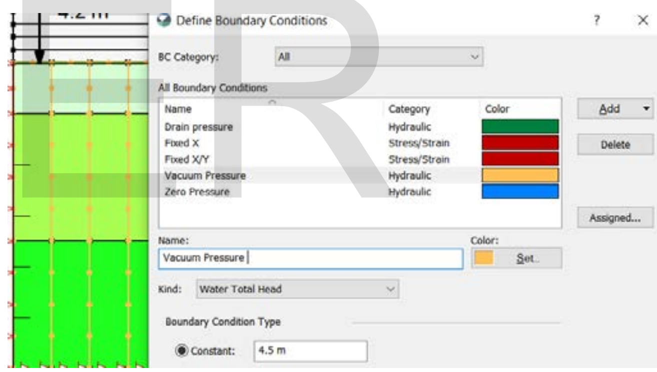

Fig. 3. Vacuum Preloading Model by Modification of Water Total Head

6 Result

Based on the numerical analysis, deformation for soil preloading is vary from 1.4m to 0.4m. the variation is high due to the physical of soil backfill and sloping, this create a problem around perimeter of improvement area, because the preloading is maybe less than operational load. total displacement in soil preloading also indicate there is an outward movement of soil body that may lead into instability during improvement process. Soil preloading total displacement result could be found in these following figures.

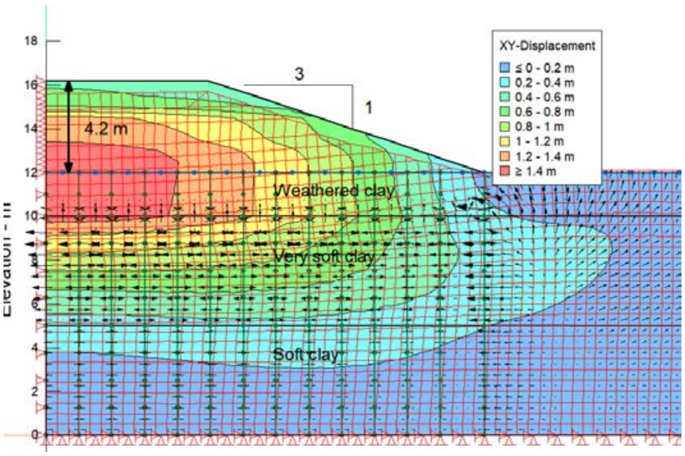

Fig. 4. Total Displacement Result (Soil Preloading)

Total displacement analysis using vacuum preloading model in other hand show less maximm settlement but more equally distributed settlement along the improvement area. Consolidation settlement is only 1.2m using vacuum preloading compare with 1.4m maximum consolidation with soil preloading. Eventhough the preloading pressure is almost equal around 75kPa. Vacuum preloading also induces an inward soil movement rather than outward like what happen on soil preloading. This effect will be favorable if vacuum preloading is need to combine with soil preloading to increase the stability. but this lateral effect also not favorable if there is any nearby structure or utilities around improvement area.

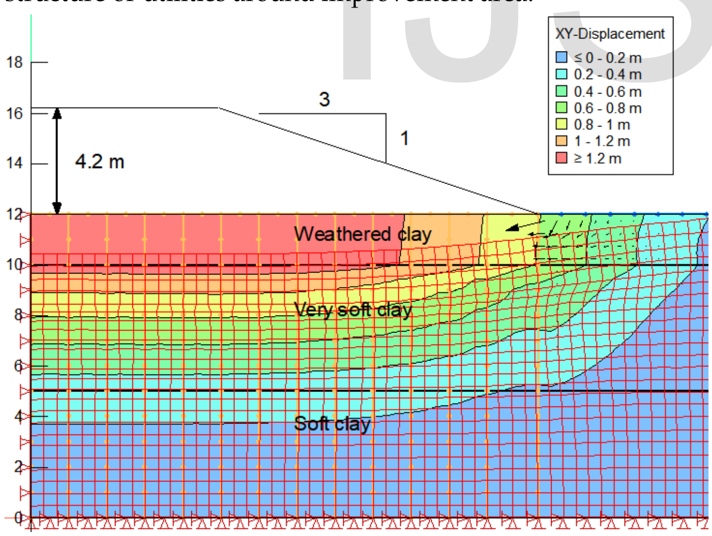

Fig. 5. Total Displacement Result (Soil Preloading)

7 CONCLUSION

Numerical model with finite element method has been successfully model the behavior of soil deformation during improvement with vacuum preloading. There is a difference behavior between vacuum preloading and soil preloading eventhough the pressure is same. Further analysis that focus on pore water pressure or lateral movement using numerical model is beneficial to check the improvement effect not only inside construction area, but also toward surrounding structure or utilities.

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