CHAPTER V
CONCLUSIONS AND DISCUSSIONS

5.1 Research Conclusions

5.1.1 The Gain of the Research

The study has been developed based on the combination of finite element analysis and laboratory experiments to propose a new appropriate method, which can be widely applied for soft ground improvement by vacuum preloading method. To avoid the risks of instability of embankment, the prediction behavior of soft soil during performance of vacuum preloading method should be concerned significantly not only in the laboratory but also at the field. The simulation vacuum preloading method using tri-axial apparatus is proposed to predict the behavior of soft soil improvement and the increasing of undrained shear strength of soil specimen at any degree of consolidation in the laboratory at Hokkaido University. The undrained shear strengths of soil, at 40%, 70% and 100% of vacuum consolidation, are gained at 43.2kPa, 53.8kPa and 62.49kPa, respectively by using tri-axial apparatus.

None boundary axisymmetric soil cell has been used to model the behavior of soft soil treatment by vacuum preloading method. This condition suits the on-site real soil condition. Two cases of drainage boundary of soil cell indicated that the consolidated time of drainage at boundary is faster than at center of the soil cell by ratio T_{hNC}/T_{hNB}. However, deformations of the specimens are in the same shape and value with the same preloading condition. Results of experiments by tri-axial apparatus agree with FEM model. It is suggested that the solution is highly reliable and technologically feasible to predict the behavior of soft soil improvement during the performance of vacuum preloading method.

The simulation by Tri-axial apparatus is the effective method to determine the increasing rate of soil strength corresponding to loading rate during consolidation process. In addition, its aim is to restrict using field test, which can cause damage of the airtight sheet membrane and loss of vacuum pressure during vacuum preloading construction. In this simulation, the normal size of specimen, which can be retrieved from the field, is conducted only one week instead of one month with large specimen.

The performance of vacuum consolidation for soft ground at Nakhorn Sri Thammarat Airport by applying technology from Maruyama Company, Japan, has achieved the required objectives. Vacuum pressure was maintained at high magnitude of 80kPa even more than 90kPa via the collection tank system to split water and air separately throughout the construction process. The average settlement is gained at 57cm, with more than 90% degree of consolidation after 135-day vacuum operation only. The construction period accelarated sigfinicantly compared to the conventional method. The settlement rate of 1mm/day was measured at the last 12 days prior to closing vacuum operation. These results indicate the effectiveness of this approach.

The vacuum pressure were generated overconsolidated state of soil, the minimum OCR values gained at 1.20. The embankment improved by surcharge and vacuum pressure can be compensated the actual loading in the future.

5.1.2 The Advantages of Using the Vacuum Preloading Method

The advantages of using the vacuum preloading method as follows

- Vacuum preloading causes isotropic stress increment in both vertical and horizontal directions in sub soil, and the corresponding lateral displacement occurred inward. Consequently, the risk of shear failure can be minimized even at higher rate of embankment construction, resulting in an increased rate of soft soil consolidation.
- The average vacuum pressure from 70 to 85kPa, generated under membrane sheets by pumping, is equivalent to 3.50m - 4.50m height of embankment. The embankment at the beginning earthwork can be constructed rapidly without any risk. The height of surcharge can be replaced by vacuum pressure to gain the same degree of consolidation.
- It is not necessary to design the land manes to restrict the instability of embankment due to large lateral deformation, which always occurs during soft soil improve by conventional method.

- The pollution in the environment does not exist during performance of vacuum consolidation method because only non-chemical material is used in this method.

5.1.3 The Factors Effect on Effectiveness of This Method

The increasing bearing capacity of soft soil can not be determined via the usual method during vacuum preloading. Hence, field date measurement and laboratory prediction are very important to control instability of the embankment, and to ensure the effectiveness of perfomance of vacuum consolidation. The instrumentations are used effectively to control and minimize the instability of the embankement at the site.

The dropping of water head and soft soil subsidence causes vacuum pressure reduction, which can be disappear completely as the large thick soft soil layer improved by conventional vacuum technique. Applying the separated tank the vacuum presure can be maitained during construction.

The effectiveness of this method based on many factors however can determine some main factors as shown below:

- Capacity of vacuum pumping systems
- The sealing and protection of the airtight sheets method
- Soft soil condition and ground water level
- Effectiveness of the vertical band drains.

5.2 Limitations and recommendations of the Study:

Because of limited research time, the Kasaoka clay samples in Japan were used to simulate behavior of soft soil improvement by vacuum consolidation instead of the extruded soil samples from the site at Nakhorn Sri Thammarat Airport in order to ensure the results obtained from simulation are accurate and consistent.

The membrane damage, caused by using sand and rock particles instead of a uniform sand layer, leads to extend the construction time of some zones to fix the leaked vacuum pressure points during earthwork. Finally, the total construction budget has increased significantly and affected whole project.

The construction process must be done carefully during performance of vacuum consolidation method. It is very important and necessary to protect the airtight sheet membrane. Three 0.3mm thickness layers of airtight sheet should be designed to prevent any risk that may occur during construction.