CHAPTER III
RESEARCH METHODOLOGY

3.1 Introduction

Nowadays the vacuum preloading consolidation method becomes the popular method to improve soft soil. This method is an effective method of improving soft soil conditions. With the merging of new materials and technologies, this method has been further improved in recent years.

The prediction behavior of improved soft soil by vacuum preloading method should be concerned significantly not only in the laboratory but also at the field to avoid the risks of instability and destruction of the embankment during construction. The efficiency of managing the progress of construction under closely control, besides the measurements in the field will reflect the design predictions. The laboratory tests were carried out in Hokkaido University-Japan and the data at Nakhorn Sri Thammarat Airport project was used to analysis the behavior of soft soil before and after vacuum preloading improvement.

3.2 Simulation Vacuum Preloading Method by Tri-Axial Apparatus

It is very important to control any risk of instability of embankment during vacuum construction, the simulation vacuum preloading method using tri-axial apparatus is proposed to predict the behavior of soft soil improvement in the laboratory, as well as to make this method become familiar and easier in the future. The tri-axial apparatus is used instead of the large-scale one, which has been performed by Bergado (1998) and Indaratna (2008). The tri-axial test on small size specimen can be carried out in one week compared to the large-scale apparatus takes one month for big specimen. In addition, the lateral deformation as well as the shear strength increase with time can determine accurately.

The modeling vacuum method to improve soft soil in the laboratory has been performed by Indaratna (2008) using the large-scale apparatus and follows Terzaghi's one-dimensional consolidation theory. The results obtained from this modeling partially evaluated the behavior of soft soil reinforced by vacuum preloading method in the laboratory. Using the large specimen 45 cm x vacuum preloading method in the laboratory. Using the large specimen 45 cm x 90 cm in diameter and height respectively in the large-scale apparatus, the time used for this test was more than one month.

The horizontal deformation ε_r during the tested time, which is the typical deformation of soft soil improvement by vacuum, and also the increasing of shear strength, could not be measured. So far, the controlling surcharge processing during vacuum construction has not been discussed sufficiently.

The new method is proposed using tri-axial apparatus to simulate the comprehensive behavior of soil improvement by vacuum preloading method in the laboratory to support the engineering task quickly. In addition, it is desired to make the method become familiar in the future.

The finite element method (FEM) is used to analyze two cases of drainage condition at the boundary and center of the axisymmetric soil cell.

The study aspects to solve these matters are as follows:

1) Simulation the behavior of soft soil improved by vacuum method by tri-axial apparatus under axisymmetric consolidation condition;

2) The lateral deformation and vertical settlement are concerned during soil improvement by vacuum preloading method;

3) Evaluating the degree of consolidation during soil improvement;

4) Combination surcharge and vacuum preloading to estimate the increasing shear strength);

3.3 Tri-axial Apparatus

Tri-axial apparatus can clearly evaluate the failure mechanism as well as the capacity of increasing shear strength of soil in the laboratory. From the tri-axial test, the result parameters are used to predict the behavior of soil in the field during construction.

Under vacuum pressure condition alone, the soil mass at depth is subjected the isotropic stress status (K=1). With flexible functions of the tri-axial machine is as shown in **Figure 3. 1**, the isotropic condition of the soil mass can generate the same vacuum condition by controlling the lateral earth pressure (K).

During vacuum condition, the surcharge loading can be generating as axial fore by the loading rod at top of the machine. The deformations of soil specimen in vertical and horizontal direction are measured during testing to evaluate the behavior of soil specimen.

The specimen is covered by rubber membrane and placed in the water tank; therefore the friction between circular soil specimen and the cell is eliminate, which is different to the oedometer apparatus.

The steel plates at the ends of specimen are as the impervious layer; only radial drainage is induced during consolidation. The filter paper covers around the boundary of specimen and overlaps the porous discs at the both ends of specimen as the drainage layer. For the large-scale oedometer apparatus, the drainage was established at the center of specimen.

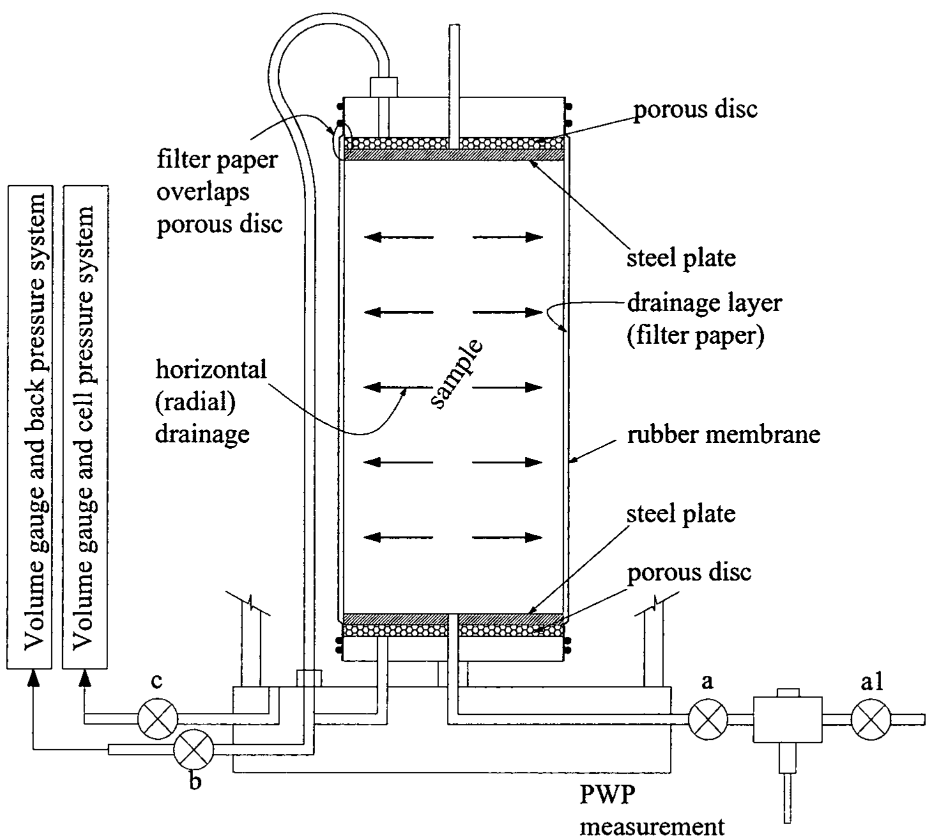


Figure 3.1. Scheme Tri-axial apparatus

The FEM has been used to define the different between the drainage path conditions of specimen, and defines the correction factor for this simulation. The boundary conditions were illustrated in the **Figure 3.2**. The assumptions

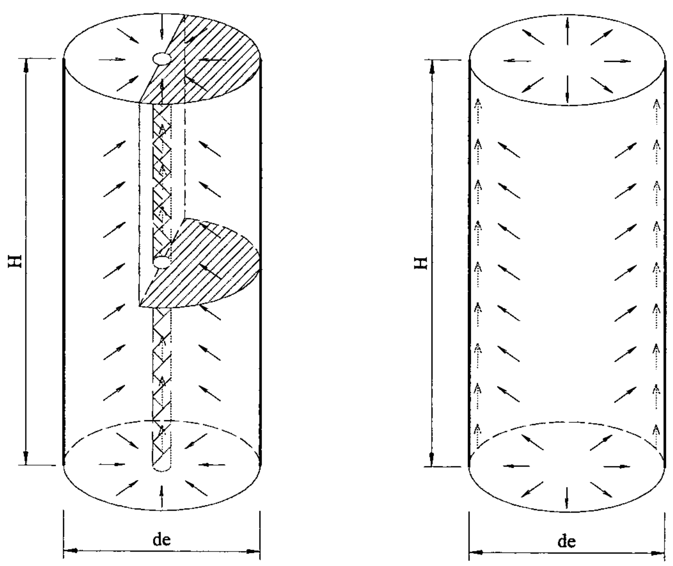
1) Soil mass as subjected vacuum pressure follows axisymmetric consolidation.

2) Under vacuum pressure only, soil mass will be subjected the Isotropic stress state, it mean that the coefficient of horizontal earth pressure (*K*) equal to one, while for the surcharge only (K) value can calculate from Eq(3.1).

3) For the soil mass, the vacuum pressure is distributed along to the specimen is uniform.

$$K = 1 - \sin\varphi \qquad (3.1)$$

Where, φ - the friction angle of soil



a) Drainage at center b) Drainage at outer boundary

Figure 3.2. The modeling of axisymmetric cell in FEM

3.4 Prediction of DOC of Vacuum Preloading Method

3.4.1 Field Monitoring and Instrumentation

The field instrumentations for monitoring of embankment behavior include surface settlement plates, deep settlement gauge, piezometers, and inclinometers. In this project area, the instrumentations include standpipe piezometers, surface settlement plates, and observation wells. The data measured at the site is very important to assessment vacuum consolidation period. There were six types of instruments including surface settlement plates, sub surface settlement gauges, electric type piezometer, inclinometer, and PVC sub surface settlement gauges, electric type piezometer, inclinometer, and PVC Automatic Acquisition Unit and water discharge record meters. The types of instrumentation are shown in **Figure 3.3.** List of functions and frequency for different types of instrumentation are shown in *Table 3.1.*

Table 3.1. List of functions and frequency of field instrumentation.

Name of instrument	Item to be measured	Frequency of measurement	
		During construction	After finished of filling works
Surface settlement plate	Vertical settlement	1 time/ day	1 time/ day
Sub Surface settlement gauge	Vertical settlement for subsoil beneath embankment	1 time/ day	1 time/ day
Electric type piezometer	Pore water pressure	Real time records	Real time records
Inclinometer	Vertical and horizontal movement at toe and some distance from toe of embankment	1 time/ day	
Vacuum pressure monitoring box	Vacuum pressure at pump and under vacuum sheets	Real time records	Real time records
Water discharge meter	Rate of water discharge and total volume of water	Real time records	Real time records

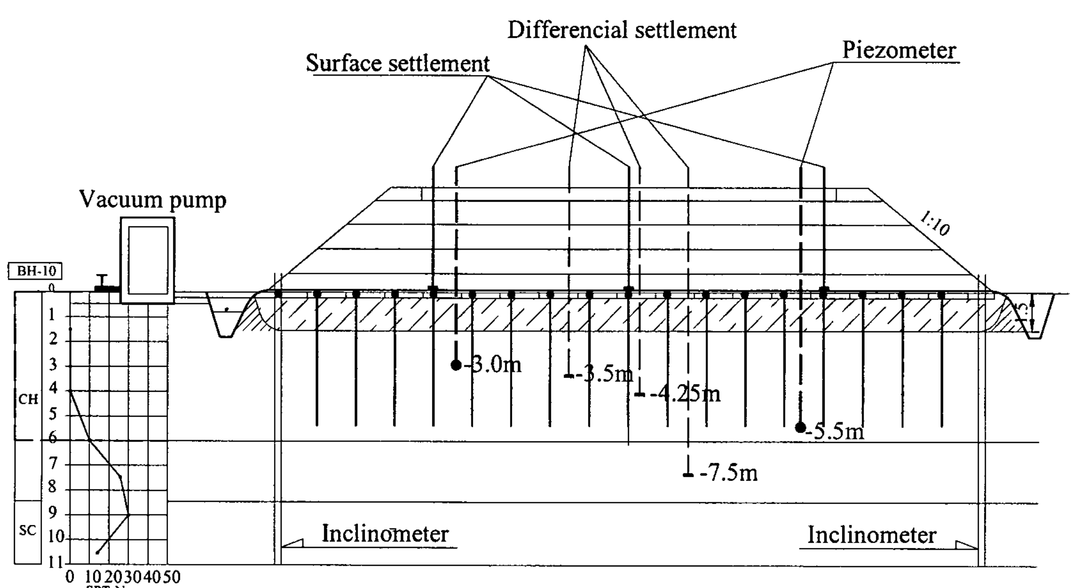


Figure 3.3. Arrangement of instrumentations

3.4.2 Asaoka Method

The Asaoka method (1978) is a method of settlement observation for one-dimensional consolidation in which earlier observations are used to predict the ultimate primary settlement. If necessary, the in situ coefficient of consolidation can also be back calculated after the analysis. The main advantage of this method is its simplicity. In common, settlement analysis conditions such as the initial distribution of the excess pore pressure, the drain length, the final vertical strain of soils, and the coefficient of consolidation are considered to be given in advance of the analysis. It is known that these estimations are quite uncertain. The graphical method can be described as follows (see **Figure 3.4**):

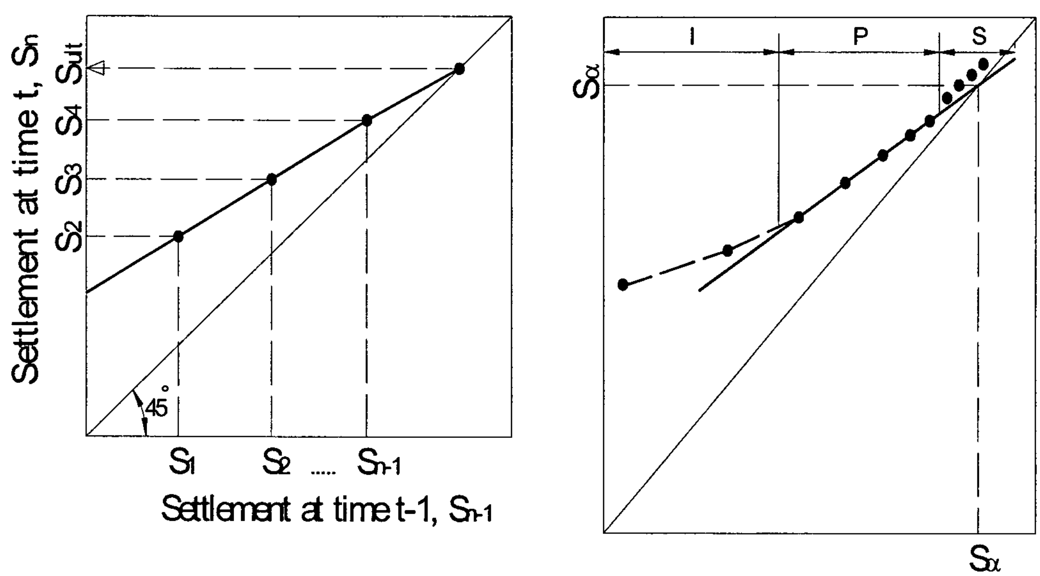


Figure 3.4. Schematic illustration of Asaoka's method

For the Asaoka method neither determination of soil properties nor measuring of the field pore pressure behavior is needed. Asaoka showed that one-dimensional consolidation settlements at certain time intervals could be described as a first order approximation as Eq (3.2):

$$S_n = \beta_o + \beta_1 . S_{n-1} \qquad (3.2)$$

Where S_1, S_2, ..., S_n are settlements observations. S_n denotes the settlement at time t_n. The time interval $\Delta t = (t_n - t_{n-1})$ is constant. The first order approximation should represent a straight line on a (S_n vs S_{n-1})-co-ordinate. The values of β_0 and β_1 are given by the intercept of the fitted straight line with the

S_n - axis and the slope. The ultimate primary settlement can be calculated with the Eq (3.3):

$$S_{ult} = \beta_o/(1-\beta_1) \quad (3.3)$$

Which also describes the intercepting point with a 45°-line because S_{ult} is given by S_n=S_{n-1}.

• From the time/settlement curve take a series of S_n values.

• From those values plot the points on a (S_n vs S_{n-1}) co-ordinate.

• Find the values β_0 and β_1 and the intercepting point with the 45°-line to determine the ultimate primary settlement

I: Initial stage of compression

P: Primary consolidation with constant C_h or C_v

S: Secondary compression