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Investigating the soil consolidation via vacuum method by using numerical analysis

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ABSTRACT: Due to increasing population and urbanization and lack of suitable land in terms of bearing capacity, construction is performed on soft soils, especially clays with low bearing capacity and excessive conventional settling characteristics. In these types of saturated soils, the construction of structures, such as large buildings, will release pore water pressure and therefore create a consolidation. One of the ways to reduce consolidation to the permissible amount specified in the regulations is to use a preload method that will require soil and embarkment operations and ultimately, necessity the removal of those embarkments. Vacuum combined with vertical drainage is an effective way to reduce the number of soil operations and associated costs, which in other words will accelerate the construction of structures and reduce costs. In this study, the effect of several parameters on the amount of consolidation was investigated by simulating soil consolidation via using the COMSOL Multiphysics and GeoStudio software. Based on the results, it was found that increasing vacuum intensity in vacuum chambers, increasing soil void ratio, and increasing bedrock depth, each of them accelerated the consolidation process. However, the number of vacuum terminals does not have a significant impact on this process.

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1- Introduction

Considering the various simplistic assumptions used in the extraction of the differential equation of the consensus of consolidation, in recent years, many researchers have worked on the real conditions of soil layers, their type of loading, and their effect on consolidation. Chai et al., in 2005, proposed a semi-experimental method for calculating the settlement and displacement at the end of soil consolidation caused by vacuum pressure [1]. Also, Chai et al. in 2008 introduced two ways to apply vacuum to the soil [2]. Following Chai et al. in 2010 proposed the method for calculating the time on the edge of the vacuumed region [3].

In the pre-loading method with a vacuum, the surface of the soil is covered with an airborne layer, and the negative pressure (via the vacuum pump) applies to the section below this coating. To distribute and spread the vacuum, drain wells and horizontal layers are used under the airborne layer. At the same time, the drainage and pumping system will drain water and reduce the degree of saturation of the soil. The drainage wells of each section are connected to a vacuum pump. If they consider several sections simultaneously, drainage wells of these sectors are linked to several drain pumps using flexible pipes. This enhances simultaneous improvement but increases the installation time and the launch will increase [4].

In this research, soil consolidation operations were simulated by creating a vacuum in soil by numerical software to investigate the effect of different parameters such as depth of bedrock, vacuum pressure, soil poison ratio, and vacuum distance interval on the consolidation process. The analysis carried out in this research was first accepted by the Comsol numerical simulation software.

2- Methodology

COMSOL Multiphysics Software [5] is a complete simulation set that can analyze differential equations of nonlinear systems by minor derivatives by finite element spaces in one, two and 3D spaces. In this research, simulations were performed by this software in a two-dimensional space and then simulated in Geostudio software [6], and verification was performed.

In choosing the soil profile information of Chai et al. in 2005 [1], which was a case study at the oil storage station in the Tianjin region, was used according to Table 1.

To investigate the effect of vacuum intensity on the amount of soil consolidation, the relative vacuum effect on soil in each simulation 0, 0.1, 0.3, 0.5, 0.7, 0.9, 1- and 2-atmospheres are considered.

For simulations at this stage, 4 variables for soil void ratio and 3 depths of bedrock depth are considered.

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Table 1. Soil characteristics for the consolidation area

Parameter	Amount	Unit
Yang Modules	60 e6	**Pa**
Poisson Ratio	0.3	**-**
Density	1900	**kg/m^3**
Cohesion	14	**kPa**
Friction Angle	35	**Deg**

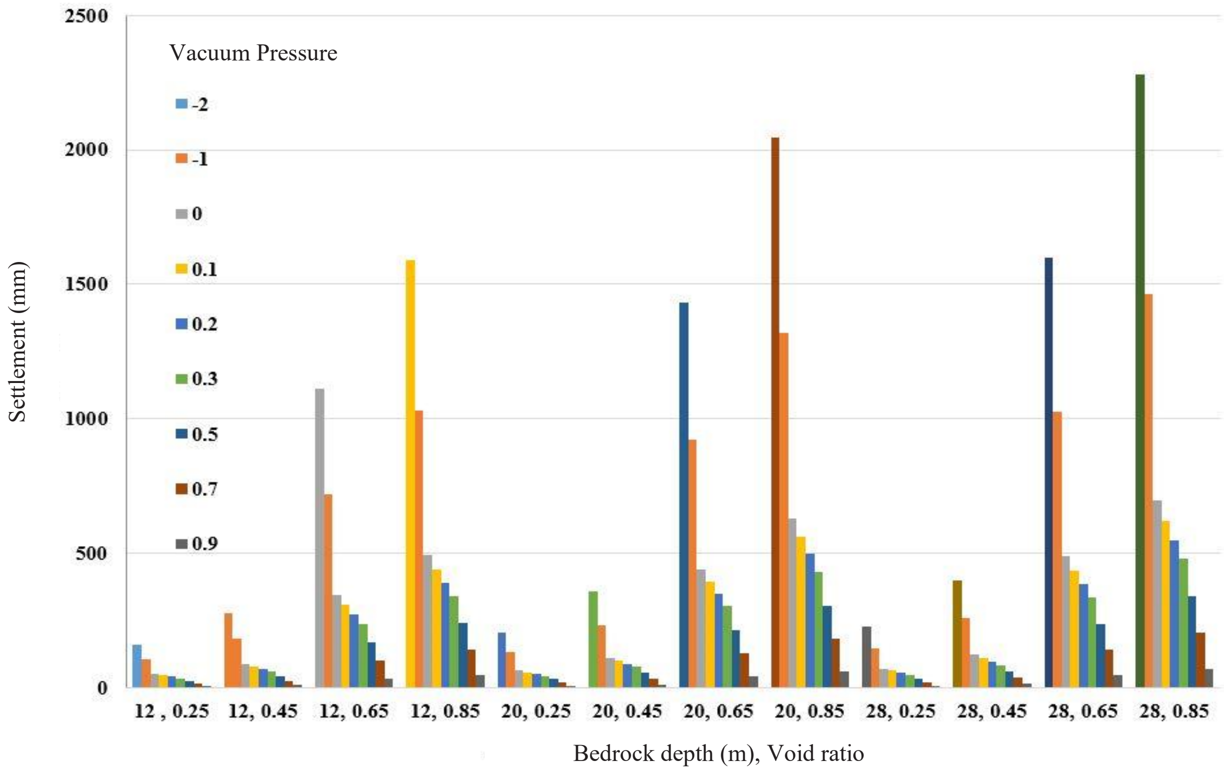

Fig. 1. Diagram of vacuum settlement by changing the relative vacuum pressure, bedrock depth, and soil void ratio

To further investigate, the effect of soil void ratio was evaluated to study the effect of this method in different geographic regions in terms of soil.

To investigate the impact of the number of vacuum terminals in the soil, the number of these terminals is changed from one to ten.

3- Results and conclusion

Figure 1 shows a summary of the results. Based on this, the general results of this research can be summarized as follows:

1- As the amount of vacuum pressure increases, with decreasing the pore water pressure, the overhead pressure increases at the same time, and therefore the consolidation settlement increases with a linear trend (according to Figure 1).

2- With increasing the void ratio of the soil, the amount of soil settlement has also increased the amount of this change depending on the parameters and characteristics of the soil, including the depth of the bedrock and the relative vacuum pressure applied.

3- With increasing the depth of the bedrock and the relative pressure of the vacuum in the soil, the effect of void ratio increases. In the proportion of more void ratio, the rate of settlement is increased. In other words, the change in internal stresses in more porous soils is much greater and therefore causes much more settlement.

4- With the increasing depth of the bedrock, the amount of soil subsidence also increases. As the effect of the applied vacuum decreases in distant places, the effect of the applied vacuum will decrease with increasing the depth of the bedrock.

5- With other soil characteristics and applied vacuum being constant, changing the number of vacuum terminals has had a negligible effect on effect on the amount of settlement. After giving enough time to the simulation system, the vacuum in the soil will expand to a certain extent in the whole range and the number of these terminals will only increase the speed of the result and will practically have no effect on the final settling rate.

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