The investigation of the Efficiency of Vacuum preloading in the reclamation of the Weak clay soil Mahshahr Khuzestan Case Study

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ABSTRACT

Vacuum preloading technology has been widely used all over the world for years. Unfortunately, in Iran, even after years of practical work, the efficiency and functioning of this technology remain unknown. Due to the extensive industrial constructions in the north and south coast of Iran, this technology can play an important role in advancing the overall goals of the project and increasing productivity due to the reduction of construction time and as a result of increasing the productivity of the entire soil improvement system. The use of vacuum pressure in order to increase the efficiency of systems containing surcharge loads and vertical drains is very effective and efficient and reduces the time required to reach the desired degree of consolidation. In this article, first, a summary of the history and basis of operation of vacuum soil consolidation systems is provided, and then the efficiency of this system is shown assuming its use for a practical project. Substrate consolidation of Mahshahr clarification unit has been selected as a case study in which the project used surcharge along with vertical drains (PVD) for soil improvement. After confirming the model, vacuum load of 30, 60, and 75 kPa was applied to the model in three states of initial surcharge of 6 meters, reduced surcharge of 3 meters, and no surcharge, and the increase in efficiency was investigated. According to the obtained results, the application of vacuum preloading significantly increases the efficiency both economically and time-wise in the soil improvement system in similar projects. The reduced slag load state of 3 meters and vacuum pressure of 30 kPa was determined as the optimal scenario in this study.

KEYWORDS

Vacuum preloading, surcharge, vertical drains, consolidation, weak clay

1. Introduction

In recent years, the construction of railroad and highway embankments and foundations of large structures on soft and unconsolidated soils has led to many advances in soil remediation techniques. Most of the important constructions in most countries, due to economic conditions, the possibility of free access, the existence of oil and gas resources and very fast developments, are carried out in areas with very weak soils with low bearing capacity, as well as with the potential of high settlements; Therefore, it is necessary to improve these soft soils before starting construction operations in order to prevent high settlements as well as differential settlements. The features of preloading with vacuum compared to the usual method of preloading are as follows: (a) The effective stress corresponding to the suction pressure increases rapidly, and the lateral displacement decreases. As a result, the risk of shear failure is minimized even with high embankment construction speeds. However, the internal displacement towards the embankment heel should be carefully considered. b) The vacuum preload pressure can be distributed to greater depths of the subsurface soil using a system of installed porous vertical drains. c) The amount of surcharge load can be reduced to obtain an equal amount of settlement, which depends on the efficiency of the vacuum system. d) Because the surcharge height can be reduced, the maximum additional pore water pressure created by vacuum preloading is lower than the conventional surcharge method. f) By applying vacuum pressure, the inevitable unsaturated conditions in the soil-drainage boundary layers are improved, which will lead to an increase in the rate of consolidation [1]. The cost of soil improvement with vacuum preloading is about 30% lower than using the usual surcharge method [9]. The efficiency of the system depends on several important factors, including: the airtightness of the system, the efficiency of the insulation between the corners of the membrane and the ground surface, and the soil conditions and the location of the water surface [1, 2]. The project site is located about 20 kilometers northwest of Bandar Mahshahr Petrochemical Special Economic Zone. The two existing tanks are located on the pile. Due to economic issues, it was decided to modify the bed of two other tanks by preloading method. Previous studies have shown that according to the geotechnical characteristics of the soil in the area, a settlement of 450 and 900 mm can be achieved by using a combination of 6 and 9-meter surcharge and vertical drains within 5 months. Preloading is the application of surcharge load on the execution site, before the placement of the permanent structure, under which primary consolidation will occur. During the pre-loading operation and with the exit of excess pore water pressure from the system, soil settlement took place and the effective stress in the subsurface loose and compressible layers increased and therefore the possibility of settlement of the structure after construction is significantly reduced [21]. The layering of the site is as follows:

Layer I: This layer starts from the surface of the earth and continues to a depth of 16 meters. This sticky layer is mostly thin clay and its strength is soft to semi-hard. One of the remarkable characteristics of this layer is the presence of sand and silt lenses at different depths, which sometimes increase the SPT number at that depth. Layer II: This layer starts from an average depth of 16 meters and continues to an average depth of 22 meters. This layer is non-sticky and mainly made of silty sand or sand silt with thin clay interlayers. In terms of density, this layer is placed in the medium to very dense category. layer III: From the average depth of 22 meters to the end of the identification depth, in most of the boreholes, a sticky layer of thin clay material has been observed again. In terms of strength, this layer is placed in the rigid to hard category [4]. The pre-loading project of Mahshahr port clarifier units will be used to check the efficiency of the vacuum system in this article. Numerical model made of plane strain type and finite element method and analyzed using Geostudio 2018 software. In this modeling, the Behavioral Model of Modified Cam Clay which obeys the closed flow law and its efficiency in the model. It has been proven that similar problems have been used [5, 6]. The elements used are Quads and Triangles and sand blanket and drains were applied as boundary conditions in the model. The impact zone around the drain is ignored. Since most of the settlement occurs in the upper 16 meters, only the upper layer is considered in the finite element modeling. Modeling details and additional explanations about the studied project can be checked in [3, 6-9].

2. Results and Discussion

In order to check the efficiency of the consolidation system with different amounts of vacuum preload, three modes were considered: 1) applying vacuum pressure of 30 kPa, 2) applying vacuum pressure of 60 kPa 3) applying vacuum pressure of 75 kPa, which is the maximum amount that can be applied in practical terms in the subsoil. It is assumed that the vacuum application system has no leaks and no interruptions have occurred during its operation. These three cases were tested with three different surcharge loading modes to get a clear picture of the effect of vacuum. In the first case (Figure 1a), it is assumed that the conditions of the project are the same as the previous ones, and we want to use the vacuum load in addition to the 6-meter surcharge and vertical drains just to speed up the implementation process of the project. It can be seen from Figure 1a that under these conditions, with an applied vacuum of 30, 60, and 75 kPa, the duration of the project is reduced by 40, 60, and 78 days, respectively, to reach the target consolidation settlement (33 cm). As can be seen, in the case of using the combination of surcharge and vacuum pressure, the time has been significantly reduced, and if time is considered a key factor in the project, this combined method can be very efficient. In the second case, it is assumed that the surcharge height is reduced by half. It is clear that in this case, with a vacuum pressure of 30 kPa, the desired settlement would have been achieved at the same time as before, while 3 meters of the embankment height has been reduced, and following that, the problems related to the embankment's stability and implementation issues have also been reduced (Figure 1b). Considering the high cost of earthmoving and embankment operations, using the combination of surcharge preloading and vacuum with reduced height is a suitable economic option to present the improvement plan. Currently, using the combination of load and reduced surcharge in most of the current projects in the world as an efficient and economic method is considered by geotechnical designers. In this case, due to the existence of a slag, there is no need to use high vacuum pressures, and as a result, the technical problems associated with maintaining high pressures and leakage in the system and the overall cost of maintaining the system are significantly reduced. Also, using this method in areas where access to embankment materials for slag construction is limited can also be considered as a desirable option. In the case of no embankment (Figure 1c), optimal performance is not observed in the vacuum pressure of 30 and 60 kPa. The reason for this is the presence of sand lenses in the first layer of soil, which has greatly reduced the efficiency of the vacuum consolidation system. In this case, despite the presence of sand lenses and the absence of surcharge, we can see that the system has reached the target on the 170th day, similar to the case implemented with a 6-meter surcharge. In the case of using a vacuum pressure of 60 kpa, in 170 days, 90% of the target consolidation settlement has been achieved, and if the operation continues, the expected final settlement will be achieved within 30 days. According to the mentioned cases, it can be seen that the use of vacuum loading alone at pressures of 60 and 75 kpa has a performance similar to that of the constructed surcharge, with the difference that in this case there is no need for embankment and excavation operations in this huge volume and immediately after the completion of the operation The operation of the next part, which is the construction of the foundation, could be started, which could save a significant amount of time and money in the project.

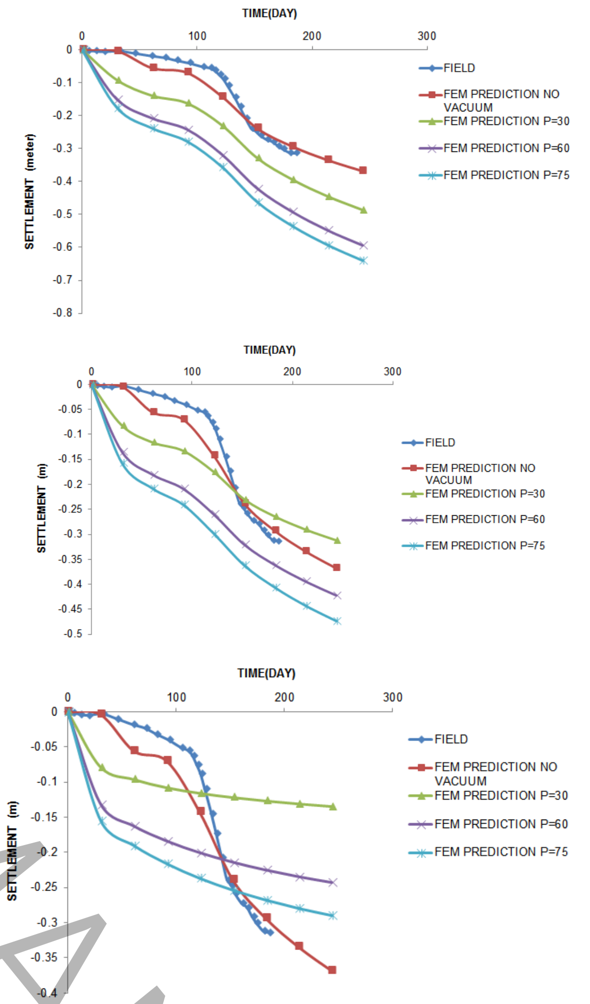

Figure1: Bed settlement under vacuum pressure of 30, 60 and 75 kilopascals for a) 6-meter surcharge b) 3-meter surcharge preloading c) without surcharge preloading

3. Conclusions

In this research, after introducing the vacuum consolidation system and describing its operating mechanism, the effectiveness of the vacuum preloading system was investigated in a case project (substrate consolidation of Mahshahr clarification unit). In areas where, due to atmospheric, geotechnical conditions or a combination of these, it is not possible to build high embankments to improve the subsoil, this technology shows its efficiency well. In cases where due to lack of time, a system that has high reliability should be used, the vacuum consolidation system can be very beneficial. Due to the fact that this system is about 30% or more cheaper than the slag load, depending on the project conditions, this system can be used alone or in combination with vacuum and surcharge to reduce costs. In this case study, although due to the presence of sand lenses, this system did not have the efficiency expected in previous similar projects, but still in the presence of 6 meters surcharge, it significantly reduced the time to reach the target, especially in the vacuum pressure mode of 60 and it was 75 kPa. In the case of a reduced surcharge of 3 meters with a vacuum pressure of 30 kPa, the system had almost the same performance as the presence of a 6-meter surcharge, and in the case of no surcharge, with a vacuum pressure of 75 kPa, it reached the target landing in almost the same time. According to the results of this research, the use of the 3-meter reduced surcharge combination mode with a minimum vacuum pressure of 30 kPa was the most economical and at the same time the most efficient soil improvement system. Due to the decrease in efficiency due to the presence of sand lenses, the importance of geotechnical investigations before starting such projects is evident. Due to the expansion of coastal and offshore constructions in the country, it is hoped that this system will also be used in similar projects.

4. References

[1] J. Chu, S. Yan, B. Indraratna, Vacuum preloading techniques-recent developments and applications, (2008).

[2] C. Rujikiatkamjorn, B. Indraratna, Current state of the art in vacuum preloading for stabilising soft soil, (2013).

[3]T. Fakharian , Mehdi zade , Mohammad loo the numerical modelling of radial consolidation and callibration of instrumentation data in Sarbandar Decanter center in Mahshahr, in: forth international conference of soil mechanic and geotechnic in iran, undefined, 2010.

[4] A. Tasalloti, K. Fakharian, A. Mehdizadeh, Preliminary investigation of instrumentation in decanter units preloading project in Mahshahr port (South-west of Iran), 2.۰۱۰

[5] M.C. Yapriadi, I. Sumarli, A.J.J.J.M.T.S. Iskandar, Evaluasi Settlement Menggunakan Surcharge Preloading Dengan Pvd Pada Proyek Di Bandung Selatan, 3(3) (2020) 911-922.

[6]S.M.A.Z. Mohammad Mehdi Pardsouie the investigation of the percentage of improvement in the case of applying vacuum pressure along with PVD and surcharge (part 2), in: the second Iranian national conference on structure , earthquake and geotechnical engineering, Mazandaran, 2011.

[7] S.M.A.Z. Mohammad Mehdi Pardsouie The numerical investigation of soil improvement of Mahshahr decanter unit with surcharge and embankment preloading (part 1), in: the second Iranian national conference on structure , earthquake and geotechnical engineering, Mazandaran, 2011.

[8]M.M. Pardsouie, M. Mokhberi, M.H.J.A.R.i.C.E. Pardsouie, The Importance of Incorporating Hydraulic Modifier Function versus Step Loading in Ground Improvements Including Vacuum Preloading, 4(2) (2022) 54-60.

[9] M.M. Pardsouie, M.H. Pardsouie, S.M.A. Zomorodian, M.J.J.o.C.E. Mokhberi, M. Application, Numerical Study of efficiency of the Vacuum Preloading in Weak Clay Treatment (a case study), 6(2) (2022).