

# The Influence of Vacuum Preloading Method Process on the Nearby Foundation in a Project

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**Abstract.** The vacuum preloading method is a useful and common method in treating soft soil foundation. Lots of pore water is discharged and the foundation occur large deformation in vacuum preloading procedure. The large deformation may affect the stability of the nearby foundation, leading to cracking and differential settlement. This paper analysed the influence of vacuum preloading process on the nearby foundation with numerical simulation method based on an engineering case. The vertical and lateral displacement was calculated and the effect of implement vacuum preloading on nearby foundation was evaluated.

## 1. Introduction

The Delta region is the natural gathering place, and it is also the main area of economic development. The land area of the Delta region is formed by alleviations, and the bearing capacity of foundation is weak. The vacuum preloading method is a useful method in treating soft soil foundation.

The foundation exhibits large deformation in applying vacuum load, and this settlement may affects the stability of existing building on the nearby area. The research on the influence of vacuum preloading method on nearby buildings attracted extensive attention, and some scholars did contribute on this subject. In 2001 [1], Yu and Zhu tested the soil index variation of existing foundation close to the vacuum preloading area, and proposed an influence estimation method. In 2005 [2], Chen and Zhu analyzed the influence of vacuum preloading process with different depths of trench, different modulus of shelter pile, different permeability coefficients of shelter pile and different lengths of shelter pile. In 2006 [3], Ai carried out in-site test and numerical simulation to reveal the mechanism of the influence of vacuum preloading process on nearby area. The results show that the influence degree depends on soil strength of the existing foundation. In 2006 [4], Ai analyzed the influence of vacuum preloading process and the effect of prevention measures based on an engineering case. In 2008 [5], Jin et al proposed in-site model test and found that the range of influence area is within 12.5 m. The cement-mixed piles, stress-releasing trench, and root piles can observably reduce the influence. In 2008 [6], Cai et al analyzed the development of pore pressure, underground water level, settlement and lateral deformation of existing area based on an engineering case.



This paper analyzed the deformation of existing area with numerical method based on an engineering case, and the effect of prevention methods are tested as well to offer several proposals in solving the influence of vacuum preloading process on nearby area.

## 2. Engineering case description

The vacuum preloading area was a fishpond before treating. The fishpond was filled with soft soil firstly, and the vacuum load should be applied until the elevation of surface reach 2.0 m. The pre-vacuum treating lasted for 5~7 days to make the vacuum degree fall to -80 kPa. Then the former vacuum load treating process lasted for 120 days.

The nearby area had existing buildings when the fishpond was treated. And the nearby area was treated with the combination of vacuum preloading and dynamic compaction in history. In order to reduce the influence of vacuum preloading on the nearby existing area, double-row mud mixing piles was set along the border of fishpond. The spaces between two nearby piles is 500 mm, and the diameter and length of piles are 700 mm and 8 m respectively. The lengths of piles penetrating into mud are larger than 3 m. The elevation of surface in the vacuum preloading area is 2.5 m. The bottom elevation of the plastic drain board is -21 m. The bottom elevation of the cement-mixed piles is -24 m.

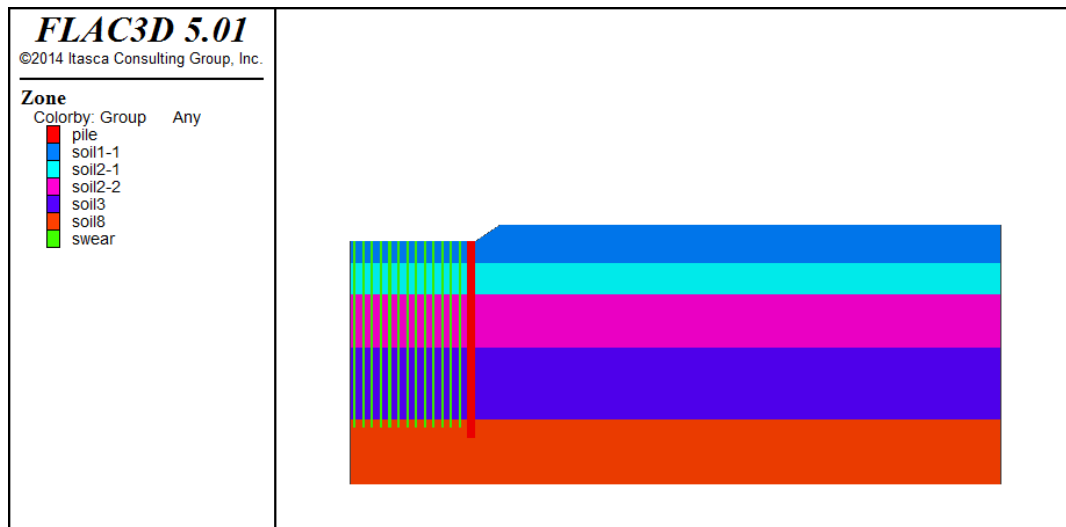
## 3. The numerical simulation models

The FLAC3D software was used in simulation. A symmetrical 2D model was established to evaluate the influence of 120 days' vacuum preloading treatment. The soil was divided into coating area and non-coating area with different horizontal permeability coefficients. The soil was modeled with Mohr-Coulomb model, and the pile was simulated with elastic model. The average service load on the existing area is 40 kPa. The lateral displacements of the soil sides and vertical movement of the soil bottom were restricted. The parameters used in simulation are shown in Table 1.

**Table 1.** Parameters used in simulation

Layer	Density (kg/m <sup>3</sup> )	Compression modulus (MPa)	Cohesion (kPa)	Friction angle (°)	Horizontal permeability (cm/s)	Vertical permeability (cm/s)	Depth (m)
Filling soil	1180	1.06	4.8	25	1.15E-07	1.15E-07	4.45
Mud 2-1	930	4.7	4.8	20	2.27E-07	1.19E-07	3.10
Mud 2-2	930	3.76	5.7	20	8.35E-08	1.76E-07	10.5
Mud 3	970	4.07	6.7	25	5.63E-08	9.83E-08	6.5
Silty clay 4-1	1490	3.64	27	26	3.02E-07	9.83E-08	2.8
Sandy clay 8	1550	2.56	20.1	25.4	5.00E-04	3.53E-04	7.15

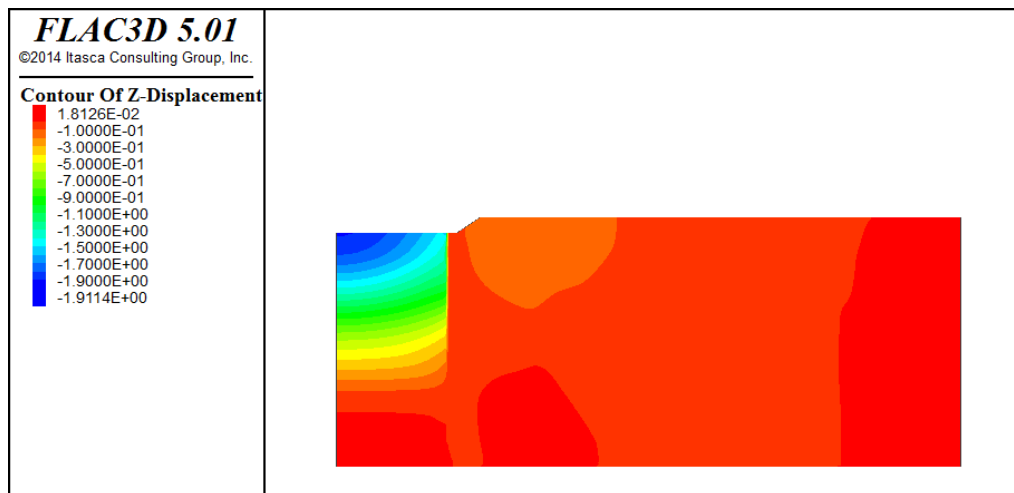
Figure 1 shows the calculating section. The left part is vacuum preloading area, and it is 14 m wide. The right part is existing area. The transition section between the two areas was simulated with a slope to prevent the non-convergence in calculations. The model is 77 m long and 31 m high, containing 40482 elements in total.



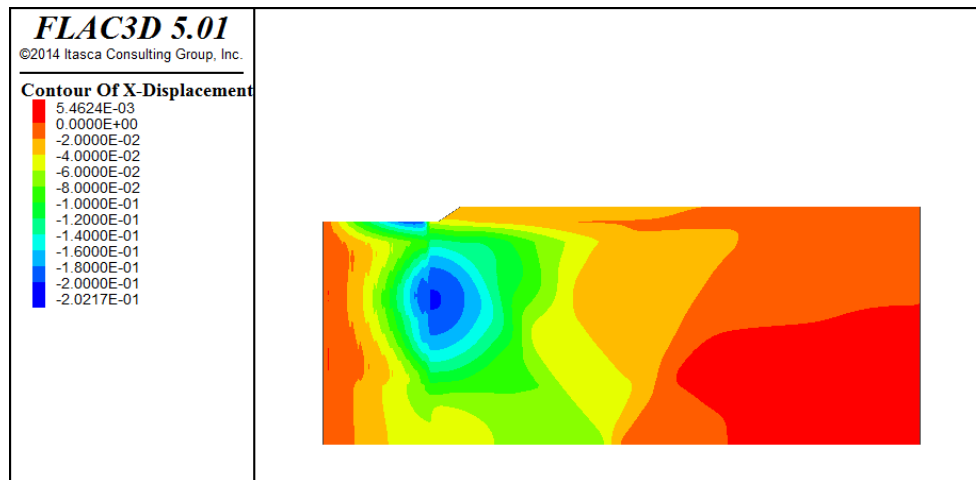
**Figure 1.** FEA model

#### 4. Simulation results

Figure 2 is the settlement of vacuum preloading area after 120 days' treatment. The largest settlement located in the middle of vacuum preloading area is 1.91 m. The settlement reduces with the increasing on distance away from middle point. The settlement at the border is 0.07 m. The existing area deformed vertically in this treatment process, and the largest settlement is 0.15 m located at the point 5 m away from border.



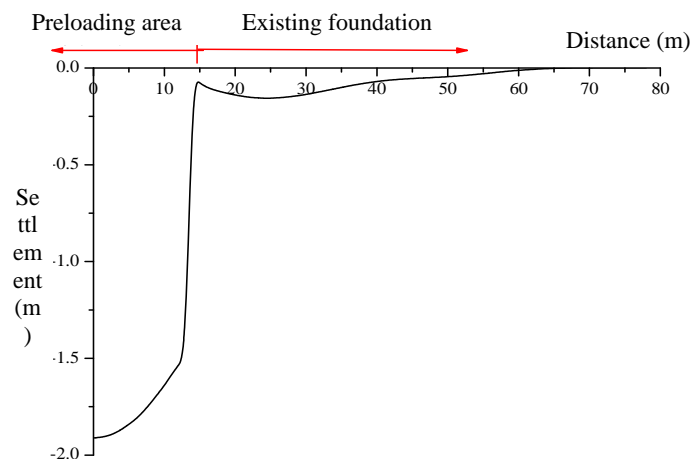
**Figure 2.** Distribution of settlement after 120 days' preloading



**Figure 3.** Distribution of lateral displacement after 120 days' preloading

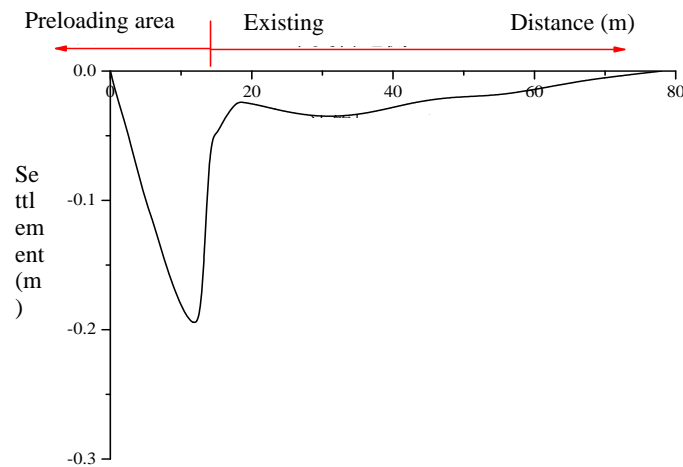
Figure 3 is the lateral displacement of vacuum preloading area after 120 days' treatment. The lateral displacement increases with the increasing on distance away from middle point. The largest settlement located at the border, and it is 0.2 m. The settlement at the border is 0.07 m. The existing area deformed laterally in vacuum preloading treating process. The lateral displacement of existing area mainly focuses with the range of 15 m away from border, and the largest lateral displacement is 0.2 m.

Figure 4 shows the surface settlement from the mid-point of vacuum preloading area to existing area. The settlement of existing area occurs within 25 m next to the vacuum preloading area. The maximum and minimum settlement is 0.15 m and 0.10 m respectively. The settlement of farther existing area is small.



**Figure 4.** Distribution of settlement along the surface after 120 days' preloading

Figure 5 shows the lateral displacement of surface from the mid-point of vacuum preloading area to existing area. The largest lateral displacement of existing area is 0.035 m, occurring at the point 15 m away from border. The average lateral displacement of existing area occurs within 35 m next to the vacuum preloading area is 0.025 m.



**Figure 5.** Distribution of lateral displacement along the surface after 120 days' preloading

## 5. Conclusion

The influence of vacuum preloading treatment on existing area was analyzed with numerical simulation method, and the main conclusions are as followed.

(1) The main settlement of existing area occurs with 25 m next to the border. The maximum settlement is 0.15 m, and the average value is 0.1 m. The settlement of foundation out of 25 m range is small.

(2) The lateral displacement of existing area main focuses with 15 m next to the border. The largest lateral displacement is 0.035 m. The average lateral displacement of existing area more than 35 m away from border is 0.025 m.

(3) The existing area was treated with the combination of vacuum preloading and dynamic compaction in history. Therefore the settlement and lateral displacement caused by 120 days' vacuum preloading process is small. The cement-mixed piles also make contributions to vanish the influence of vacuum preloading process.

## References

- [1] Z Yu, Y Zhu, Z Yu. Analysis of Affected Surrounding Area of Soft Soils Improved with Vacuum Preloading Technique [J]. China Harbour Engineering, 2001 (01): 26 - 30. (In Chinese).
- [2] L Chen, J Zhu. Finite element analysis of safety measures for affected soft ground area by vacuum preloading [J]. Chinese Journal of Rock Mechanics and Engineering, 2005 (S2): 5712 - 5715.
- [3] Y Ai. Field study and calculation analysis of the influence on surrounding soil due to vacuum preloading [D] Hohai University, 2006.
- [4] Y Ai, N Cai, C Ke. Measures for reducing lateral deformation of soil outside vacuum preloading area [J]. Journal of Hohai University (Natural Sciences), 2007 (06): 686 - 689. (In Chinese).
- [5] X Jin, J Yu, X Gong. Study on environmental effect induced by vacuum preloading and its control method [J] Rock and Soil Mechanics, 2008 (04): 1093 - 1096+1102. (In Chinese).
- [6] N Cai, Z Dong, G Zhang. Influence of Improvement of Hydraulically Reclaimed Land by Vacuum Preloading Technique upon Surrounding Environment [J]. China Harbour Engineering, 2008 (06): 20 - 23. (In Chinese).