Numerical simulation on effective range of plastic drainage plate under vacuum preloading

Huiqiang Gao [a], Huarong Yuan, Peilin Ning

College of Civil Engineer, Guangdong communication polytechnic, guangzhou, 510650, China

[a]ghuiqiang@qq.com

Abstract

The study on effective range of plastic vertical drain (PVD) is very significant for the effect of vacuum preloading. The effective range of PVD is analyzed by numerical simulation. The conclusions show that the effective range of PVD is not always a cylinder but is gradually changing into a cylinder; the effective range of PVD will be a cylinder finally when the consolidation time is enough.

Keywords

plastic drainage plate, effective range, numerical simulation.

1. Introduction

Blow fill foundation mainly adopts drainage consolidation method to reinforce foundation. Many scholars do a lot of research about drainage consolidation method. Barron[1], Hansbo[2], Xie Kang-he[3],etc. do further research about sand drain consolidation theory under positive pressure. Dong Zhiliang[4] ,etc. establish the analytical consolidation theories of sand drain foundation under negative pressure. These theories assume that the effective range of sand drain is cylinder and the cylinder gradually spread. Another hypothesis is that the length of sand drain and the soil thickness are invariant during the consolidation process. In the current design and calculation of drainage consolidation method, the effective range of sand drain also equivalent to a cylinder.

Based on current theories and design methods, the strength of soil between the PVDs will be same in the depth direction after vacuum preloading. But in engineering practice,it often occurs that the reinforcement effect is not good in the fill soil foundation treatment[5][6]. The soil strength is higher at the ground surface soil or the soil near the PVD, and it is relatively small between the PVD. Thus, existing theories are certain limitations and the effective range of PVD is not a cylinder.

Numerical simulation is a important means of studying vacuum preloading, and many scholars do a lot of research about it. P.SH.Chen regarded soil as porous media and combined the project of vacuum preloading in Nansha Port of Guangzhou, a large-scale 3D FEM model is set up. The calculated results agree well with the monitored data in situ[7]. ZH.L.Dong set up 3D finite element model, it is found that the consolidation deformation with 3D FEM of ground installed by sand-drain presents more accurate than of plane-strain method[8]. The Duncan-Chang constitutive model was developed based on the FEM program automatic dynamic incremental nonlinear analysis (ADINA) by SH. Ying. Comparing the calculated results with the field data, it showed that the calculated results were more approximate to the field data when considering the influence of the bended PVDs[9].

The effective range of PVD is defined as the consolidation degree of the soil is achieved by the design requirement (the degree of consolidation is generally 80%). In order to analyze on the effective range of PVD, three dimensional finite element model of vacuum preloading is established. By analyzing the change of pore water pressure in the process of vacuum preloading, the consolidation degree of soil is calculated, and the change law of effective range is analyzed.

2. Establish model

Fig.1 and Fig.2 is calculation model. Model length and width=1.05m×1.05m, Model height=20m, silt layer thickness=20m, PVD depth=20m, PVD size=4.5mm×100mm, smear zone size=0.35m×0.35m. Boundary conditions are: top soil applied -80kPa of excess pore water pressure, displacement freedom and is permeable surface; the side and bottom of the model are horizontal and vertical displacement constraints, and impervious surface.

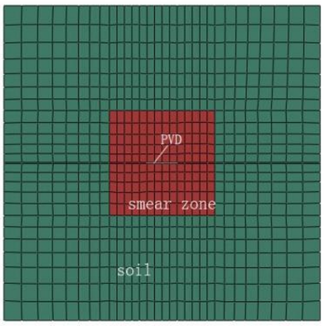


Fig.1 model plan

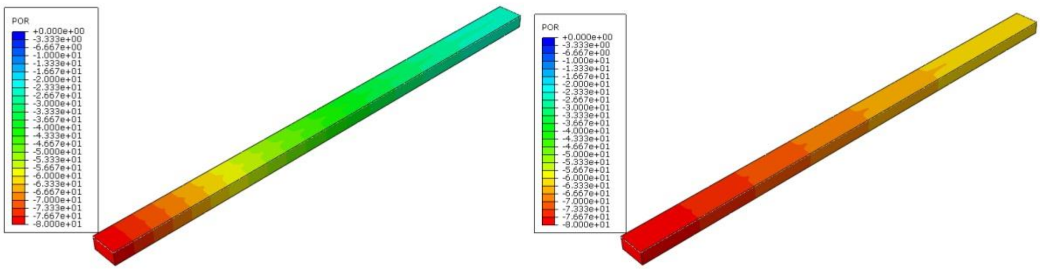
Fig.2 3D finite element model

The value of the parameters of dredger fill is as follows: k_h=6.91e-4m/d, k_z=3.46e-4m/d, k_h/k_z=2, k_{w0}=86.4 m/d, H=20m, c_h=1.59e-2m/d. The parameters of PVD are as follow: r_e=0.525m, r_s=0.175m, r_w=0.035m, $n=r_e/r_w$=15, $s=r_s/r_w$=5.

The purpose of this paper is to analyze the change process of PVD effective range, and the accuracy of the numerical results is not the focus. So the material model is Mohr-Coulomb model, and unite type is 8-node elements.

3. Results analysis

Fig.3 is could map of pore water pressures when consolidation time are 30 days and 90 days, and which is not considering the permeability changes.



(a) consolidation time is 30 days (b) consolidation time is 90 days

Fig.3 excess pore water pressure of soil when the permeability is constant

As shows as Fig.3, in the vacuum of 30 days, the pore water pressure of the shallow layer on the surface of the soil and the water near the drainage plate is basically -80kPa, and the pore water pressure dissipation faster. With the increase of the depth, the pore water pressure along the radial direction of the PVD gradually decreases, which shows that the degree of the dissipation of pore water pressure is smaller and smaller. After 90 days of vacuum, the range of pore water pressure reaches -80kPa is greatly increased, which indicates that the dissipation of pore water pressure gradually spread to the deep soil.

For a more intuitive analysis, the soil consolidation degree is deduced according to excess pore water pressure at different depths and consolidation time when r_e=0.525m. As shown in Fig.4

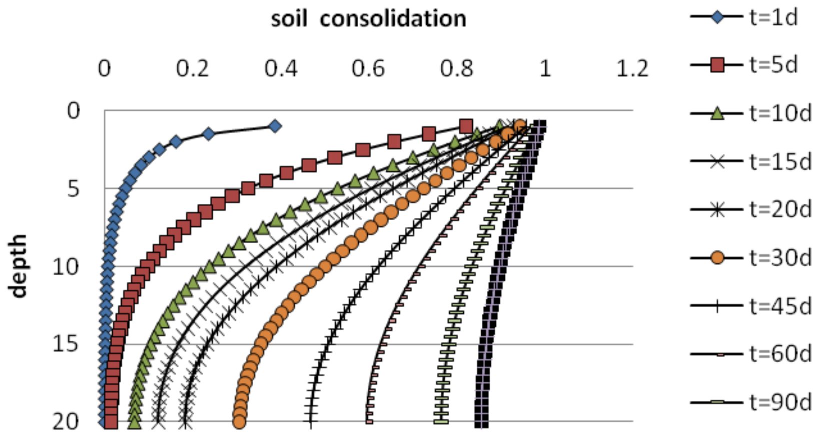


Fig.4 Curves of soil consolidation degree when re=0.525m

Fig.4 show that when the beginning of a vacuum, re=0.525m of soil consolidation is still relatively small, only the surface of the soil to reach 80% of the degree of consolidation. The degree of consolidation of the soil in the depth of 3.5m is 80% when the vacuum time is 30 days. In the 90 days of the vacuum, the depth of the soil mass of 12.5m reached 80%, and the 12.5m of the soil still did not reach the design requirements. Therefore, in the general vacuum pumping time (90 days), the effective range of the PVD did not reach cylinder, but a truncated cone.

When the vacuum is 120 days, the consolidation degree of the soil is 80% in the range of 20m. Therefore, as long as the vacuum pumping time is long enough, the effective range of the PVD can reach the cylinder.

The degree of consolidation of the soil at the depth of 20m from the initial consolidation degree, to 30 days 30%, to 60% days 60 to 120 days to reach 85%. These results show that the soil consolidation is first in the shallow layer and near the drainage plate to reach 80%, and then to the depth of soil and far away from the PVD. Therefore, the effective range of the PVD is not spreading out with a cylinder, but a change process, and Eventually reach the cylinder

4. Conclusion

In foundation treatment of vacuum preloading, effective range of the PVD is not spreading out with a cylinder as the consolidation time, but a change process, and Eventually reach the cylinder; When it has enough consolidation time, the final effective range of plastic PVD is a cylinder that its radius is r_e=0.525m.

Acknowledgements

Natural Science Foundation.

References

[1] Barron, R.A. Consolidation of Fine Grained Soils by Drain Wells, Trnas. ASCE, 1948, Vol.113, 718-742.

[2] Hansbo S. Consolidation of Fine-grained Soils with Prefabricated Drains. proceedings of the 10th international conference on soils mechanics and foundations engineering, Stockholm,Sweden,1981, Vol.3,pp.677-682

[3] Kanghe Xie, Guoxi Zeng. Consolidation theories for drain wells under equal strain condition [J]. Chinese Journal of Geotechnical Engineering, 1989, 11(2): 3-17.(in chinese)

[4] Zhiliang Dong. Consolidation theory on heaped load & vacuum preloading of sand drain foundation [J]. Waterway Engineering, 1992,(9):1-7. (in chinese)

[5] Zhiliang Dong, Gongxin ZHang, Qi ZHou, et al. Research and application of improvement technology of shallow ultra-soft soil formed by hydraulic reclamation in Tianjin Binhai new area[J]. Chinese Journal of Rock Mechanics and Engineering, 2011, 30(5): 1306-1312. (in chinese)

[6] Zhiliang Dong, Qi ZHou, Gongxin ZHang, et al. Field comparison test of reinforcement technology of shallow ultra-soft soil in Tianjin Binhai New Area[J]. Rock and Soil Mechanics, 2012, 33(5): 1073－1080. (in chinese)

[7] Pingshan Chen, Yinguang Fang, Haihong Mo,et al. Analysis of 3D FEM for soft foundation improved by vacuum preloading [J]. Chinese Journal of Geotechnical Engineering, 2009, 31(4):564–570. (in Chinese).

[8] Pingshan CHen, Haihong Mo, et al. Comparison of numerical simulation with finite element method for vacuum preloading[J].Chinese Journal of Rock Mechanics and Engineering, 2008, 27 (11)：2347–2353.(in Chinese)

[9] Shu Ying,Pingshan Chen. Effects of bended plastic drainage on consolidation caused by vaccum preloading[J].Chinese Journal of Rock Mechanics and Engineering, 2011, 30（S2）：3633–3640.(in Chinese)