Numerical Analysis on Post-enhancing Method Used in Soft Soil with Concrete Mini-Pile

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Abstract. Post-enhancing Method with concrete mini-pile is a new way to strengthen subgrade. The displacement and pore pressure of the soft soil during construction are studied in this paper through numerical simulation. The figures of development of subgrade deformation and sub water pore pressure show that there is a comprehensive function in post-strengthen foundation with small concrete pile.

1. Introduction
Recently, post-processing technology used in the construction progress of high fill sub grade located on the soft ground is a newly developed roadbed treatment methodology (Figure.1). It has been successfully performed in many highway projects and has achieved good social and economic benefits.

![Figure 1 Construction technology of concrete mini-pile](image)

Figure 1. Construction technology of concrete mini-pile

Bearing capacity and uncoordinated settlement of sub grade are key problems in expressway construction in soft soil areas, and Post-enhancing Method with concrete mini-pile, which has been successfully used in many constructions of super highway, is a new technique to increase bearing capacity and reduce differential deformation of sub grade.

A numerical model of special software which describes the whole construction progress is used in the analysis [1, 2]. Based on the numerical model, the development tendency of the deformation, pore water pressure, and effective stress is analyzed.

2. General engineering geology
The project is located in the alluvial plain of the Yellow River. Assuming that the sub grade and filling soil are elastic-plastic material and the pile is elastic material, and the main soil from top to bottom are distributed as Figure. 2 and Table 1.
The development of computer technology has provided conditions for people to use computers for large-scale numerical analysis and calculation. Using numerical analysis technology, especially finite element method, to solve the complex non-linear problems in geotechnical engineering has become one of the main means of current research [2, 3].

In the model, eight-node hexahedral pore pressure element (C3D8P) is used for soil, and eight-node hexahedral linear non-conforming element (C3D8I) for pile (Figure.3) [2, 4]. Based on the numerical model, the development tendency of the deformation, pore-water pressure, and effective stress is analyzed.

### Table 1 Material parameters

| No. | Deformation modulus $E$ (MPa) | Poisson ratio $\nu$ | Density $\rho$ (kg/m³) | Permeability coefficient $K$ (m/s) | Cohesion $c$ (KPa) | Internal friction angle $\phi$ (°) |
|-----|-------------------------------|--------------------|------------------------|-----------------------------------|-------------------|-----------------------------|
| 1. Pile | 20000 | 0.2 | 2400 | — | — | — |
| 2. Clay | 15.3 | 0.27 | 1730 | $10^7$ | 27 | 28 |
| 3. Silt | 4.7 | 0.4 | 1650 | $10^8$ | 10 | 13 |
| 4. Silty clay | 10.3 | 0.28 | 1720 | $10^3$ | 25 | 20 |
| 5. Gravel | 25.6 | 0.23 | 1850 | $10^4$ | 24 | 16 |
| 6. Filling | 28.9 | 0.25 | 1800 | $10^6$ | 32 | 25 |

### 3. Calculating model of sub grade

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### 4. Simulation results and analysis

Based on the numerical model, the development tendency of the deformation, pore-water pressure, and effective stress is analyzed in the sub grade, and the characteristic of the distribution during the construction and service period is also discussed [5].
4.1. Pore-water Pressure
In order to reflect the better characteristics of post-treatment method in reducing the pore-water pressure, the original model of high fill sub grade using post-treatment method (Figure 4.A), and the comparison model of filling before no post-treatment process under the same conditions are established (Figure 4.B). Comparing Figure 4.A and Figure 4.B, it can be found that the post-processing method can release the excess pore water pressure rapidly in the soft soil layer in roadbed.

Figure 4 Pore water pressure nephogram of original model (A) and contrast model (B)

4.2. Soil deformation
Figure 5 and Figure 6 show the vertical deformation nephograms of soil before the post-processing and 10 years after the post-processing. Before the post-treatment, the vertical deformation of the fill gradually decreases from the middle to both sides, and the differential settlement of the fill soil layer is obvious. After the treatment, the settlement of the soil in the filling is more uniform, and the differential settlement in the filling is smaller due to the formation of composite foundation.

Figure 5 Vertical deformation cloud map of fill
Figure 6 Vertical deformation nephogram after 10 years processing

Figure 7 shows the horizontal displacement nephogram of the soil from 4 days (Figure 7.A) after drilled holes to 10 years (Figure 7.B) after completion of construction. In the short term, the ultimate horizontal displacement of the high fill sub grade mainly concentrates at the top of the shoulder and under the foot of the high fill slope (Figure 7.A), and the deformation direction is opposite. Ten years after completion of construction, the ultimate horizontal displacement of high fill sub grade is located on the surface outside the high fill and in the deep soil under the composite foundation(Figure 7.B), and the direction of deformation is opposite[6].

Figure 7 Horizontal displacement nephogram of soil
4.3. Central effective stress

Figure 8 shows the variation curve of the vertical effective stress at the midpoint K of the silt layer, and compares it with the sub grade without post-treatment. Vertical effective stress in the soil at the centre of silt soil rises rapidly within two days of drilling, and the effective stress changes little after the completion of construction. Without the sub grade after treatment, the vertical stress in the soil gradually increases with the consolidation of the soil, and finally tends to be stable.

5. Conclusion

A numerical model which describes the whole construction progress is used in the analysis. Based on the numerical model, the development tendency of the deformation, pore-water pressure, and effective stress is analyzed. The characteristic of the distribution during the construction and service period is also discussed.

The calculation model of the axial stress based on the elastic theory is obtained and the result of the theory model is compared with that of the numerical model. The result proves the validity of the theory model. According to the result of this research, post-processed composite foundation with mini-piles is more useful better capacity than many other methods of sub grade consolidation.

The computer can simulate the structural stress change and the ground deformation trend in the whole construction process. In learning and understanding the control parameters of engineering construction process, computer technology has incomparable technical advantages.

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