Comprehensive Analysis of Application Effect of Various Soft Foundation Treatment Technology in Highway Reconstruction and Expansion Project

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Abstract

The subgrade subsidence and pavement cracking are becoming a serious problem during the service period of highway. The mixed soil-cement pile curtain wall (MSCPCW) was installed at the boundary of old and extended pavement for the expansion project of the soft soil subgrade section of highway. The settlements of soft soil foundation and construction process were simulated using the elastic-plastic finite element analysis software. The numerical simulation results are in line with the experimental results, which show that the numerical model is accurate to describe the deformation of cement mixing pile and soft soil foundation. The combined method of MSCPCW and foundation treatment can effectively control the new and old roadbed difference settlement for expansion highway project.

Keywords

Soft Foundation Treatment, Highway, Mixed Cement Pile, Deformation.

1. Introduction

In some areas of our country, the highway is gradually reduced, and the widening of the existing highway is increasing. The widening embankment in deep soft roadbed of highway Extension Project will generate additional settlement and uneven settlement between new and old subgrade. The differential settlement will cause the old subgrade deformation. It will be seriously caused the crack of subgrade and road surface, and sinking speed [1, 2]. The case of engineering shows that the effect of single foundation treatment is limited [3, 4]. To solve the problem of uneven settlement of new and old roadbed, the variety of soft foundation treatment technology should be used in treatment of soft soil.

This paper recommends an actual engineering case to inspect the measuring accuracy of soft foundation settlement with the finite element method software of PLAXIS and experimental analysis. The PLAXIS also can be used to analyze relevant parameters how to impact the deformation of highway under operation.

2. Engineering Case

A highway soft soil foundation is widely distributed, the embankment top width 26m, height of 5.5m, the slope 1:1.5, bottom width for 42.5m. The physical mechanical properties of soil are shown in Table 1. Soft foundation adopted surcharge preloading drainage consolidation method, bagged sand drain spacing of 1.0 m, with a diameter of 70 mm, plum shaped arrangement, design depth of 10m.

Table 1. Parameters of soil in soft ground

soil layer	H/m	γ/kNm^{-3}	E_s/MPa	c/kPa	Φ/(°)	v	K_h/md^{-1}	K_v/md^{-1}	K_{ve}/md^{-1}
silty clay	0.7	18.6	4.0	34.0	5.0	0.20	8.3E-3	8.3E-3	0.249
muck	8.0	15.0	0.43	11.7	11.4	0.35	2.85E-4	4.23E-4	8.7E-3
medium-coarse sand	2.3	19.2	10.2	2.0	28.0	0.30	1.0	1.0	-
silty clay	15	18.8	6.68	26.6	13.4	0.30	5.5E-4	5.5E-4	-
embankment fill	5.5	20.0	30.0	10	28	0.3	1.0	1.0	-

3. Numerical Model

Due to symmetric embankment, the numerical model is established as the half embankment of the highway with finite element modeling (FEM) , see Fig. 1, ground depth 26m, horizontal 100m. The numerical models of soil foundation and embankment are used elastic perfectly plastic and specific values of the parameters are shown in table 1. The boundary conditions are also considered. Left boundary for the axis of symmetry is undrained with vertical free, horizontal constraint; upper boundary is drainage with vertical and horizontal fixed; right boundary is undrained with vertical free and horizontal fixed; Lower boundary is drainage with vertical and horizontal free.

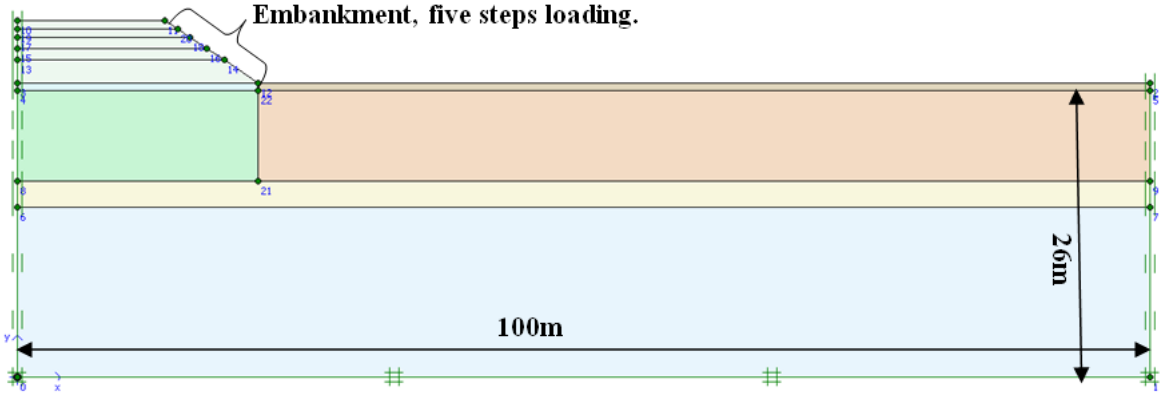

Figure 1. Numerical model

To address a problem of meshing manhole, this paper adopts equivalent vertical permeability coefficient method proposed by Chai. JC. The sand drained ground can be converted into equivalent permeability coefficient greater than natural foundation and the coefficient Kve can be seen the last row in table 1[5]. The embankment construction using thin-layer intermittent adding method can simulate the actual construction situation as soon as possible and the specific construction process is shown in Table 2.

Table 2. Duration of embankment loading

process of embankment	construction time（d）	preloading time (d)
the first (2m)	15	
the second (1m)	55	
the third (1m)	60	
the fourth (0.7m)	65	
the fifth (0.8m)	5	300

4. Numerical Analysis Results

From Figure 2 it can be seen that the largest settlement lies on the center of embankment toward each side gradually decreasing. The settlement contour is U-shaped distribution and the slope foot is slightly

uplifted. These theoretical results are consistent with the actual situation. In contract, Figure 3 shows the largest lateral deformation lies on each side and the small lateral deformation is on the center.

The curve of settlement- time of embankment center is shown in Figure 4. It deduces that the calculated curve is close to the measured curve, which means the numerical model enables to accurately predict the soft foundation settlement process of change over time.

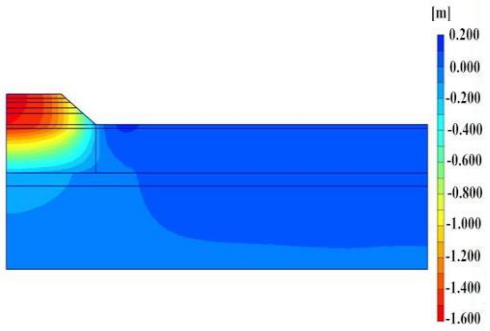

Figure 2. Vertical displacement of embankment construction

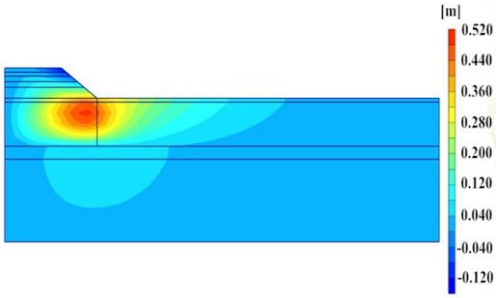

Figure 3. Horizontal displacement of embankment construction

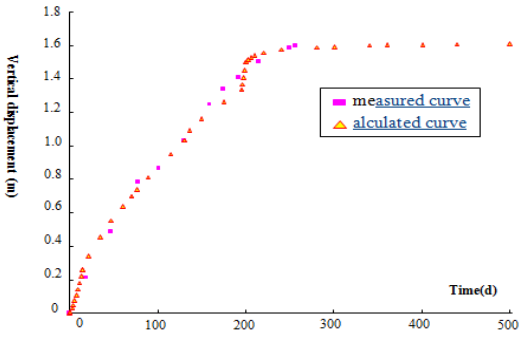

Figure 4. Comparison of measured vertical displacement and vertical displacement of subgrade Center

5. Combination of Mscpcw and Composite Foundation

Figure 5 shows the numerical model of composite foundation with cement mixing piles[6]. The cement mixing pile is arranged under the new embankment. And the spacing is 2m. In this part, the finite element method is used to analyze based on plane strain, thus the cement mixing pile with a certain spacing is equivalent to the cement mixing pile wall according to the equivalent principle (seen equation 1).

$$E_c = (1-\frac{d}{s})E_s + \frac{d}{s}E_p \tag{1}$$

Where Es is the elastic modulus of the soil; Ep is the elastic modulus of the pile; d is the pile diameter; s is the pile spacing.

According to the equation (1), the equivalent elastic modulus was calculated as 35.3MPa. Other parameters of mixing pile with curtain. Figure 6 shows the numerical model of composite foundation

with curtain. Figure 7 indicates that the use of cement mixing pile composite foundation of new embankment settlement is smaller, but still lead to uplift in the central of roads. And there is producing additional settlement near the shoulder. The use of cement mixing pile curtain can greatly reduce the impact of the new road loading on the old road, and smaller settlement after construction, which can meet the actual needs of the widening highway project.

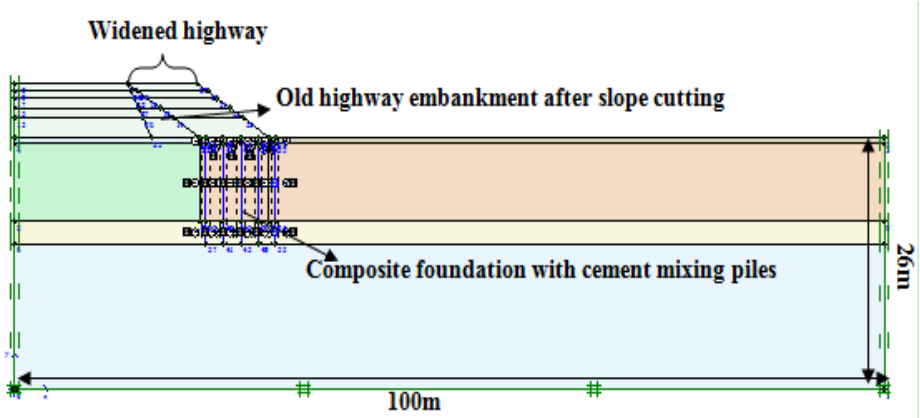

Figure 5. Numerical model of composite foundation

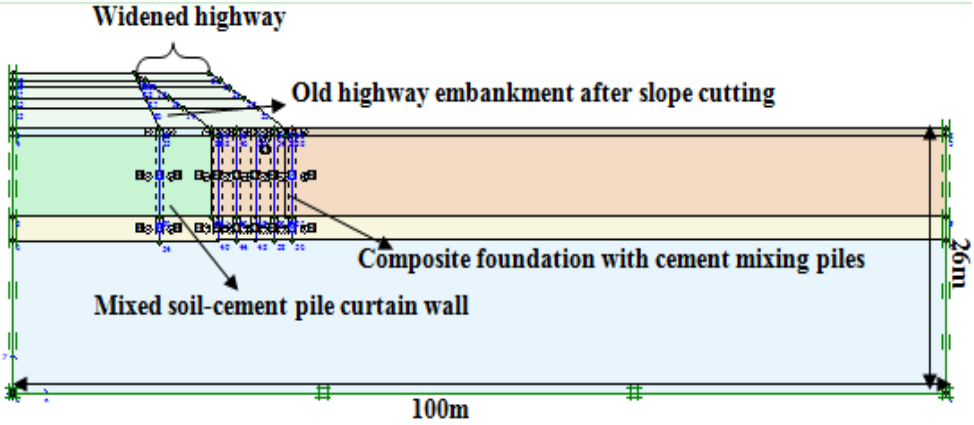

Figure 6. Numerical model of MSCPCW and composite foundation

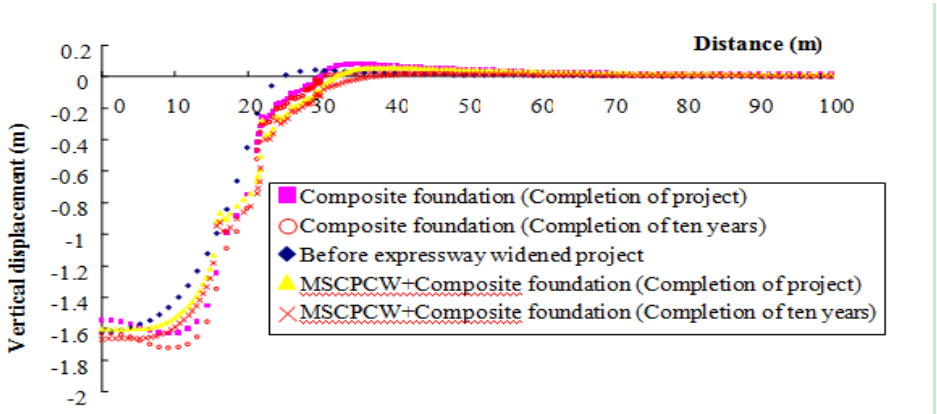

Figure 7. Lateral distribution of vertical displacement at the top of Subgrade by using MSCPCW and composite foundation

6. Conclusion

The numerical analysis results show that the numerical model can predict the deformation of the soft soil foundation of highway in service period, and the reliability of the numerical model is verified, and it can be used as a theoretical model for the follow-up study.

The combined method of MSCPCW and other foundation treatment can effectively control the new and old roadbed difference settlement for expansion highway project.

References

[1] Ye,G.B. 2013.New technology of foundation reinforcement.Beijing:mechanical industry press. (In Chinese)
[2] Qian,J.H, Yin,Z.Z.1996.Geotechnical principle and calculation of Chinese.Beijing: Water Conservancy and Hydropower Press. (In Chinese)
[3] Liu,Z.X.,Tang,L.S.2003.Lateral extrusion of soft soil under embankment settlement analysis. Engineering2:1-4. (In Chinese)
[4] Ma,S.D. 1995.The lateral displacement of soft clay foundation under embankment Journal of Huaqiao University (NATURAL SCIENCE EDITION) 16 (2): 165-167.
[5] Chai,J.C.,Shen.S.L.&Miurra N, et al.2001.A simple method of modeling PVD improved subsoil.Journal of Geotechnical and Geoenvironmental Engineering127 (11):965-972.
[6] Deng,R.2014.Analysis of Subgrade Stability Considering Ground Water Level Fluctuations. Journal of Railway Engineering Society1:37-41.