RESEARCH ON UNEVEN SETTLEMENT OF SUBGRADE WITH MICRO-PILES

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ABSTRACT

The micro-pile of Qingdao-Yinchuan Expressway K555+070-K557+710 was used to control the uneven settlement of the embankment. The earth pressure was monitored by site-placed pressure box, subgrade deformation was calculated, and Midas/GTS was used to establish the subgrade filling and operation model. The model is divided into three phases: completion, operation period and post-treatment analysis. By comparing and analyzing the numerical simulation results and the actual monitoring data, it is found that the differential pile settlement of the subgrade by the micro piles can effectively control the vertical settlement and horizontal displacement, and greatly improve the stability of the subgrade. The effect of micro piles on uneven settlement is obvious, and the optimal vertical pile spacing is 3m. Provide reference for similar projects.

Key words: Micro pile; Numerical simulation; Fill subgrade; Uneven settlement

1 INTRODUCTION

Filler subgrade deformation and destruction has always been a difficult problem to be solved in highway construction and operation. Improper handling can easily cause uneven roadbed settlement and road surface cracking. This not only makes the quality of the project difficult to guarantee, but also the safety of the vehicle will be greatly threatened. Therefore, it is particularly important to find effective and reasonable methods to deal with roadbed deformation. At present, there are many methods used for the treatment of uneven settlement of foundations. Commonly used methods include drainage consolidation, impregnation and solidification, viscous compaction and reinforced soil methods. The treatment of micro piles has been widely used in foundation treatment because of its advantages of low cost, good reinforcement effect, and simple construction.

The micro pile refers to a pile with a diameter of 70-250mm and a length of less than 30m. The use of spiral drilled holes, strong reinforcement and pressure grouting into piles of reinforced concrete in-situ piles, also known as small-diameter drilling piles, borehole irrigation micro-piles, small piles or micro-piles. The patented technology invented by Lizzi of the Italian company Fonddeile in the 20th century was named after the post-construction shape as "root." The pile body can be vertical or inclined, or can be arranged as a three-dimensional structure of the mesh system, called the network structure root pile.

This paper carries out on-the-spot monitoring of the subgrade reinforced by micro-piles for the Qingyin Expressway K555+070-K557+710, and simulates the deformation of the subgrade at the completion, operation, and after-treatment. Simulated pile length 9.5m, vertical spacing 3m. In order to simulate the deformation characteristics of the micro pile as realistically as possible, the characteristic parameters and contact parameters of the pile were loaded and calculated respectively. The aging factor is controlled by the time-course load. The settlement amount output after the completion of the filling is the sum of the deformation of each soil layer during the entire construction period. The output calculation results during the operation period are 44 months after the roadbed deformation. After the treatment, the output calculation result was pile-up and the roadbed deformation after 12 months of operation. By comparing the monitoring data of each stage and the micro pile reinforcement simulation results, the micro pile reinforcement effect was evaluated.

2 OVERVIEW OF ENGINEERING GEOLOGICAL DISASTERS

2.1Experimental Section Geological Survey

According to previous studies, the natural foundation of the roadbed consists of silt, silty clay and clay. There is a local fine sand interlayer, where the natural groundwater content W is 15.4%-33.2%, the porosity ratio e is 0.528-0.991, and the compression modulus Es is 5.05-13.56 MPa. Compared with the survey data during the construction period, the degree of consolidation can reach 82.08%-91.92%.

2.2Monitoring point layout

Through the implementation of the physical test project, 36 earth pressure boxes were buried in the soil near the 12 micro piles in the culvert at K557+348, and 6 earth pressure boxes were buried in the soil near the two micro piles in K557+680. , conduct observations. For the micropile in the emergency parking zone, the static bearing test was used to obtain the bearing capacity of the single pile. For the micropiles in the construction area, the small strain test was conducted using a random extraction method to evaluate the integrity of the pile body. After the completion of the construction, seven observation sections were set up and a total of 42 settlement observation points were used to evaluate the characteristics of deformation settlement.

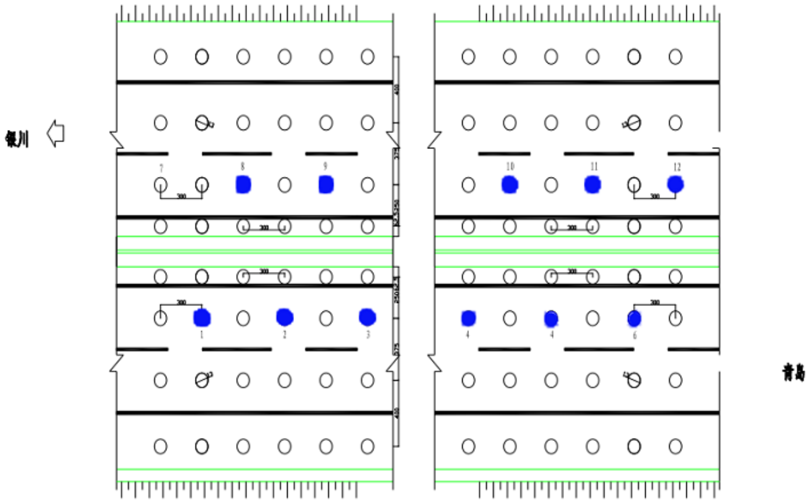

Figure.1 Schematic layout of K557+345 earth pressure box
(Note: The circle indicates the position of the micro pile, and the solid circle indicates the pressure box)

2.3 Monitoring results and settlement analysis

2.3.1Monitoring and survey data

After processing the monitoring and survey data, it was obtained: after the operation period and after the treatment, the subgrade settlements were 25.6 cm and 0.55 cm, respectively. The horizontal displacement at the foot of the slope is 4.01 cm, 0.04 cm, and the horizontal displacement at the shoulder is 2.72 cm and 0.08 cm.

2.3.2Analysis of the reasons

The direct cause of uneven settlement and cracking of the roadbed is the compressive deformation and local shear failure of the natural soil layer. In the case of uneven load, foundation differential settlement began to occur. The resulting differential settlement reaches the limit of the shear strength of the foundation soil, causing the shear failure of the foundation soil structure. Due to the appearance of cracks, atmospheric precipitation poured into the foundation; resulting in the softening of the foundation, the bearing capacity decreased immediately; the settlement of the roadbed accelerated and the cracks extended and widened.

3 NUMERICAL SIMULATION ANALYSIS

3.1Analysis of the conditions

3.1.1Calculation model

According to the parameters provided in the special study report, combined with the needs of this study, the design model along the route direction is 1m. The cross-section width of the foundation is set to 78m and the foundation thickness is 30m. The roadbed filling is 6.6m high, the top of the roadbed is 28.0m wide, and the floor width is 46.0m. The distance from the center of the road surface of micropiles is 1.625m, 2.5m, 3.75m, and 4.0m, respectively. The design model is shown in Figure 2.

The model boundary constraints are set as follows:

1 The left and right edges of the model are set to X-axis direction constraints, taking u=0. (u is the x-axis direction, w is the z-axis direction, and v is the y-axis direction); 2 the front and rear boundary of the model is the z-axis direction constraint, taking w=0; 3 the bottom boundary of the model and the side boundary of the foundation are the full constraint boundary Take u = 0, v = 0, w = 0; 4 the upper boundary of the model is a free boundary, no constraint.

The initial stress of the calculation model is the self-weight stress of the roadbed.

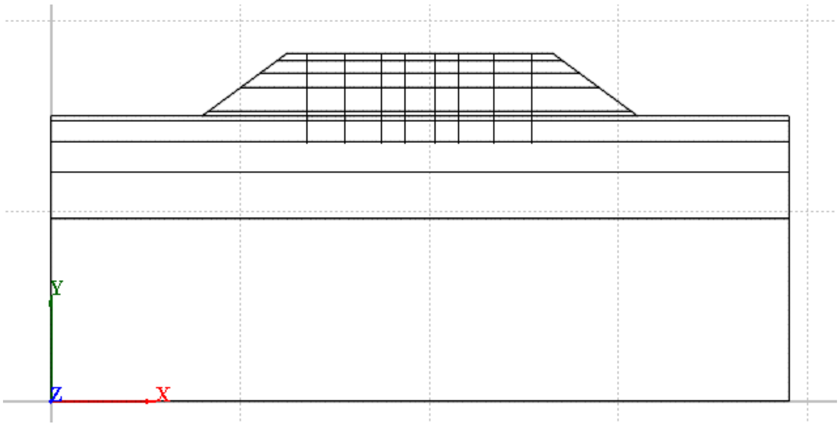

Figure 2 calculation model

3.1.2Selection of physical and mechanical parameters

Through the data analysis of the Geological Supplementary Exploration and Special Research Report on the high-speed disease treatment test section of Qingyin, the physical and mechanical parameters of the rock and soil mass were obtained. The ground consists of a total of five layers of soil, from top to bottom in order of hard shell, clay, silt layer (sand), silt layer and silty clay layer, respectively 0.5m, 2.2m, 3.2m, 4.9 m and 4.0m. The roadbed filling is divided into five layers, each with a thickness of 0.5m, 2.5m, 1.5m, 1.3m, and 0.8m. When selecting the physical and mechanical parameters of the soil, the data provided by the special research report is the main basis. With reference to other data, some data are reasonably converted and the data is consistent with the actual situation. Specific parameters are shown in Table 1, Table 2 and Table 3.

Table 1 Elastic properties of soil (lab values) (Das, 1980)

name	Elastic Modulus E(MPa)	Poisson's ratio（v）
Hard clay	6～14	0.2～0.5
Soft clay	2～3	0.15～0.25

Table 2 Physical and mechanical parameters of various soil layers

Layer number	Soil layer	thickness (m)	Bulk weight (kN/m³)	Poisson's ratio (v)	Elastic Modulus (MPa)	Cohesion (KPa)	Friction angle (°)
1	Surface clay	0.5	15.7	0.3	14	9	10.29
2	Clay	2.2	19.3	0.3	11	37	29.12
3	Silt (sandy)	3.2	19.5	0.3	3	21	21.13
4	Silt (with shell)	4.9	18.8	0.3	8	25	25.45
5	Silty clay	4.0	18.8	0.3	8	25	25.45

Table 3 Subgrade pavement material physical and mechanical parameters

Layer number	Soil layer	hickness (m)	Bulk weight (kN/m3)	Poisson's ratio (v)	Elastic Modulus (MPa)	Cohesion (KPa)	Friction angle (o)
1	Fill before rolling layer	0.5	21.8	0.17	5.1	45	28
2	Roadbed filling	2.5	16.1	0.23	3.1	16	19
3	Under the bed	1.5	19.8	0.29	3.4	17	19
4	On the road bed	1.3	20.3	0.23	4.4	17	19
5	Surface layer	0.8	22.8	0.19	12.9	48	35
6	Micro-pile	--	78	0.3	200000	--	--

3.2Completion of filling, operation and pile simulation analysis

3.2.1Calculation process

The calculation and analysis are based on the completion of the subgrade construction, the operation period and the post-piling three phases. Specifically, the following steps are performed: First, a Mohr-Coulomb constitutive model is adopted for the rock and soil of roadbed and foundation. According to the constraints described in the previous section, the elasto-plastic solution is performed under the consideration of gravity alone. The initial speed displacement field is cleared to form the initial stress field. Then activate the vehicle load and simulate the calculation of the stress and strain of the roadbed during operation. Finally, an elastic constitutive model is adopted for the micro-piles to activate the micro-piles for simulation calculation.

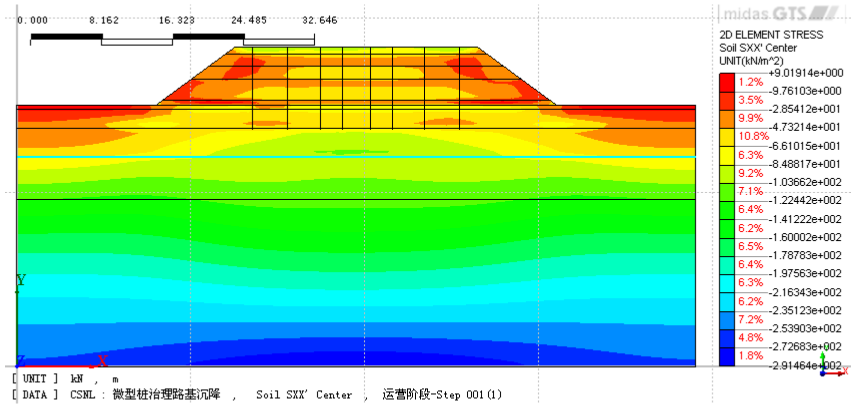

Figure 3 Horizontal stress during operation

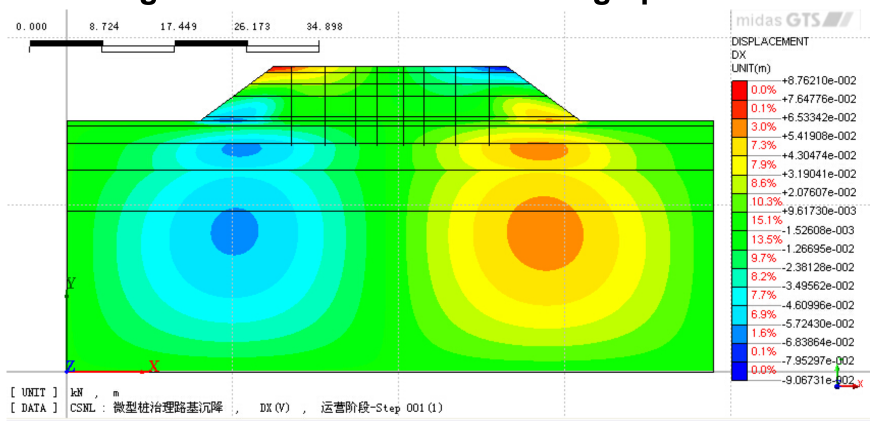

Figure 4 Horizontal displacement during operation

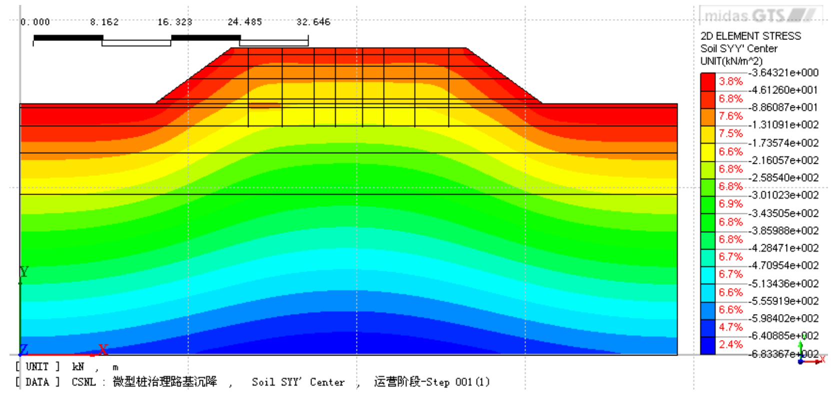

Figure 5 Vertical stress during operation

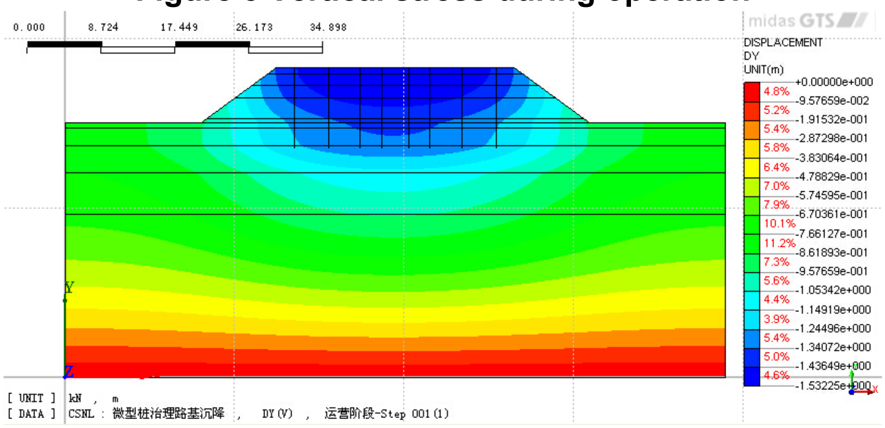

Figure 6 Vertical displacement during operation

3.2.2Simulation Results Analysis

Figure 3-6 shows the stress and displacement clouds of the foundation during operation. According to the corresponding cloud maps of the completion and management of the two working conditions, the subgrade centerline is used as the axis of symmetry, and the slope, slope line, and road shoulder at both sides of the roadbed are the concentrated areas where deformation occurs. The first two functions are rounded in a circular arc and the two shoulders shift to the center of the roadbed. The maximum displacements in the horizontal direction directly below the slope foot are 4.05cm, 1.37cm and 0.03cm respectively, and the horizontal displacement at the foot of the slope is 1.61cm, 3.81cm and 0.03cm respectively, and the horizontal displacement at the shoulder is 6.54cm, 2.53cm and 0.06cm respectively. .

The roadbed uses the centerline as the axis of symmetry, and the deformed areas are mainly concentrated on the roadbed centerline. And it spreads in an arc around, and the maximum displacement is always at the center of the embankment close to the road surface. The maximum settlement difference was obtained by the aforementioned method, and the vertical displacement amounts to 131.83 cm, 21.43 cm, and 0.35 cm, respectively.

In the simulation of micro pile treatment, by changing the vertical pile spacing (2m, 3m, 4m), trying to analyze the optimal pile spacing under fixed pile length and rock and soil conditions, to achieve the best treatment effect.

3.3Numerical Simulation Analysis Summary

The characteristics of the foundation soil during the operation period: The typical road sections have not been treated with pile-up, the roadbed filling loads and road vehicles have compacted a large area of subgrade soil. After the embankment construction is completed for a period of time, the horizontal displacement of the embankment center road surface is always zero, and the maximum vertical displacement of the embankment center road surface is 21.43 cm. However, with the passage of time, not only the horizontal displacement has increased at the foot of the embankment, but also the vertical displacement has shown an upward trend. In view of this tendency to accelerate uneven settlement, micro-pile treatment is adopted.

After pile-up treatment: Due to the small ratio of the diameter of the micro pile and the length of the pile. Under the action of the road load, the pile top will have a certain perforation effect on the road surface. At the same time, the grouting effect in the pile driving process improves the strength of the soil, improves the physical and mechanical properties, greatly improves the bearing capacity of the roadbed, and ensures the safety of the highway operation.

Optimum Longitudinal Pile Spacing: At 2m and 4m, the maximum vertical settlement at the center is 0.33cm and 2.55cm, respectively. Considering the economic investment, the middle distance interpolation method is used to determine the vertical spacing of 3m as the optimal longitudinal pile spacing.

3.4Simulation results and the measured results of comparative analysis

Table 4 Comparison of Deformation Monitoring Contrast Values and Analog Values at the Center of Slope, Embankment and Subgrade

Condition (month)	Deformation/cm					
	Monitor the conversion value			Analog value		
	X		Y	X		Y
	Slope foot	Road shoulder	center	Slope foot	Road shoulder	center
Filling completed				1.61	6.54	131.83
Operation period	4.01	2.52	25.6	3.81	2.53	21.43
After processing	0.02	0.08	0.25	0.03	0.06	0.35

From the analysis of Table 4, it can be obtained that the final settlement calculated by simulation is 21.78 cm, and the displacement in the final horizontal direction is 3.84 cm. The simulated value of the accumulated settlement at the center of the operation period is 4.17cm less than the actual measured value; the simulated value of the accumulated horizontal displacement at the shoulder is larger than the actual measured value by 0.01cm. There is a certain deviation between the simulated value and the actual measured value. However, the simulated values are close to the actual measured values, and the simulated values and the actual measured values are basically the same in the three phases. It shows that the numerical simulation can calculate the differential settlement value of the subgrade treatment of the subgrade under the test section conditions.

There is a certain deviation between the simulated value and the measured value, and the analytical inference is caused by a certain deviation between the selected physical and mechanical parameters and the actual value. Moreover, the creep effect of subgrade settlement has not been considered in the simulation calculation. In fact, the uneven subsidence of the subgrade has great timeliness.

4 CONCLUSION

Through the study of the effect of micro-pile treatment on the Qing-Yin Expressway. Comparative analysis of on-site monitoring data and simulated calculations yields the following conclusions:

1. The subsidence and horizontal displacement of the subgrade after treatment with the micropiles all decrease with time, and the subgrade can reach a stable state within a short time. Under similar engineering geological conditions, the stability of the micropiles composite subgrade is good.
2. Simulation calculation Micro piles control the uneven settlement of the filling roadbed. The micro piles show good applicability in the treatment process and results. The simulation results can predict the stress deformation trend before and after subgrade treatment.
3. Through the control variable method, the optimal vertical pile spacing is 3m under simulated rock and 9.5m pile length conditions. Provide reference for the implementation of similar projects in the future.

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