NINGDAO GAOSU GONGLU JIANSHE GUANLI LUNWENJI

宁道高速公路建设管理论文集

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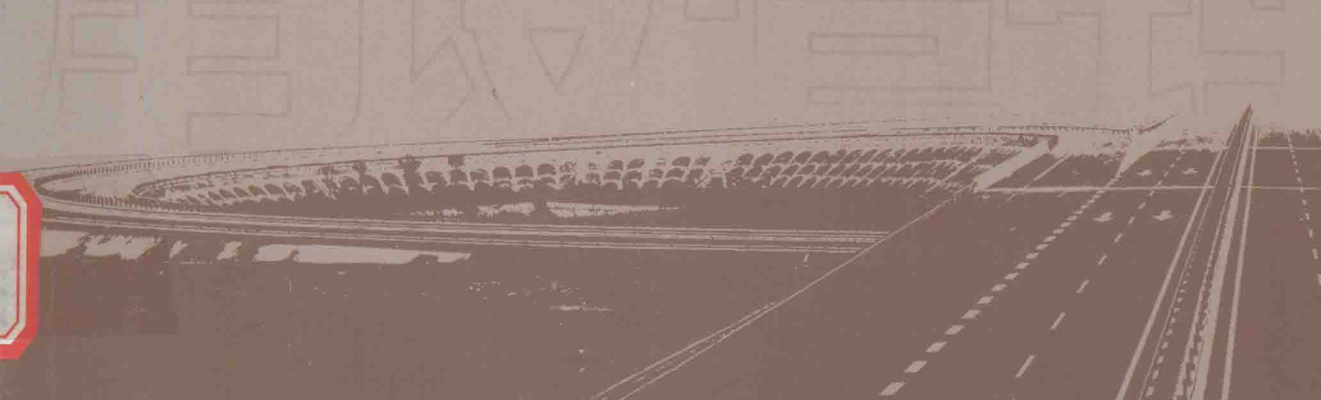

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序

寒来暑往，岁月更迭，在丹桂飘香的金秋十月，宁道高速公路即将迎来通车的美好时刻。宁道高速公路是厦蓉高速湖南境内的一段，项目全长91.538公里，穿越永州市蓝山县、宁远县、道县3地，主线采用双向4车道标准修建，投资概算为40.04亿元，总工期为4年，于2008年12月开工。该项目具有3大特点：一是沿线历史文化底蕴深厚；二是地质地形复杂，项目地处高液限红黏土和喀斯特地形地貌区，岩溶发育，施工难度非常大；三是工程造价目前全省最低。4年来，宁道公司按照湖南省省委省政府的要求，在省交通运输厅、省高管局的正确领导下，实践科学发展观，全力打造“五化三型”（国际化的理念、标准化的施工、精细化的管理、现代化的科技、创新化的文化，资源节约型、环境友好型、科技创新型）品牌高速，坚持以质量和安全为中心，奋发进取、开拓创新、勇攀高峰，各项工作进展顺利，先后获得了100多项各级荣誉。荣誉彰显出宁道人值得骄傲的成功，褒奖了宁道人敢闯敢拼、勇往直前的精神风貌。

抚今追昔，感慨万千。我们怀念大干时期激情燃烧的拼搏，我们难忘风雨兼程、无私奉献的辉煌战果。为了表达对深爱的交通事业的崇敬，我们从交通事业这波澜的大海中撷取朵朵浪花，汇集成这本论文集，旨在收集汇聚宁道人智慧的结晶，以备后鉴，更希望通过这本集子，向外界打开一扇沟通之门，以期得到广大领导、同行及专家学者的指正与引导。从论文集中，我们可以领略管理者为提升工作效率的傲人风采，追寻工程师们在建设工地风尘仆仆的矫健身姿，更可以从中一睹我省交通事业突飞猛进的伟大历程和空前成就。论文集篇幅稍长，各方面论文荟萃一册也难免光彩相掩，但我们相信，有志于交通事业的战友们必定会乐山乐水、得益匪浅。顺此，对于一贯给予我们极大鼓励和支持的各级领导和同仁们致以最诚挚的敬意。

沧海桑田，日月愈迈，历史在发展，时代在前进，但不变的是宁道人对交通事业发展的赤子情怀。我们将与时俱进、再接再厉，以一流的工作业绩、一流的管理水平，为交通事业的蓬勃发展再创辉煌。是为序。

编　者

2012年6月

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第一篇

工程技术

Numerical Simulating of Layered Buried Embankment Based on PLAXIS

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Abstract: The construction of embankment is practically a layered buried process. The settlement can't be accurately calculated by transitional settlement theoretical formula that based on the assumption that the load is applied at a time. According to the boundary conditions of a typical embankment of Ling-Nan expressway, the layered buried process is simulated based on the finite element software PLAXIS. The deformations of the location that three settlement plates buried are calculated by the method. The numerical results are compared with the observation data of settlement. The comparison shows that the simulation result is well consistent with the observation data which proves it is a feasible method to get more accurate settlement deformation result beneath layered buried embankment.

Keywords: embankment　stage filling　numerical simulation　PLAXIS

1　Introduction

Settlement control is an important guarantee for road construction quality. For traditional settlement calculation method, it is on the hypothesis that the embankment filling is finished at once, namely load also applied at a time. In fact, the embankment construction is a layered buried progress. When soil is filled to a certain height, just the soil below the height suffers the load. The top soil has no effect on settlement. The difference of layered buried embankment in deformation mechanism results in different calculation results. In order to confirm the difference, Clough and Woodward calculated the vertical displacement about the same embankment using two different methods. The calculation results of two methods differ much. Therefore, simulating the effecting of layered buried embankment by FEM is necessary for controlling the rule of stress and strain of subgrade beneath layered buried embankment. In this paper, numerical simulation technology of embankment construction is discussed according to a practical embankment of Ling-Nan expressway. The research fruit are helpful to guide embankment construction.

2　Engineering Survey

The embankment is at K16+675 mileage of the Ling-Nan expressway. The design height of the embankment is 4 m. The filling material is weathering gravel. In order to control the settlement rule, three settlement plates are respectively buried at the center and two sides of the cross-section of embankment. Fig.1 shows the practical location of settlement plates. At the same time, several side piles are buried to monitor the horizontal displacement.

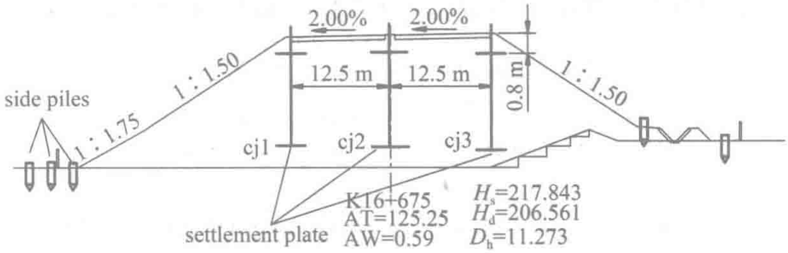


Fig.1 Settlement plates location beneath the embankment

The field settlement monitoring data shows that the settlement is very large during embankment construction. Especially for the settlement plate cj1 the total settlement and settlement rate are both large, the maximum rate reaches 11 mm/d. The total settlement reaches 100 mm when the filling height is 4.0 m. The main cause lies in thicker clay under the left side of embankment. Conversely, the total settlement and settlement rate of settlement plate cj3 are smaller because it is near to a hill and the soil is silty sand. At the same time, the left side ground surface uplifted slightly during the embankment construction period.

3 Establishment of FEM Model

In this paper, FEM software PLAXIS 8.2 is applied to calculate the settlement. It has the function of simulating the non-linear and time-related behavior of soil. So it is used to simulate the settlement deformation affected by layered buried embankment.

3.1 FEM Model

3.1.1 Model Size

The cross-section of selected embankment is non symmetrical. Considering stress dispersion ability, it is confirmed that the depth of calculation model is 21 m under the grand surface, which is 4 times of the filling height. The length of model is 180 m, which is 4 times the length of the embankment bottom.

3.1.2 Boundary Condition

According to the plane strain assumption, the FEM model is established as Fig.2. In the model, right and left boundary are both constrained in the horizontal direction, and the bottom of model is constrained in the vertical direction. According to practical embankment, the model can be divided into 3 parts, which are shown in Fig.2. Part A is embankment, B is foundation soil and C is bedrock. Node coupling method is applied to solve interface mechanics problems among A, B and C part.

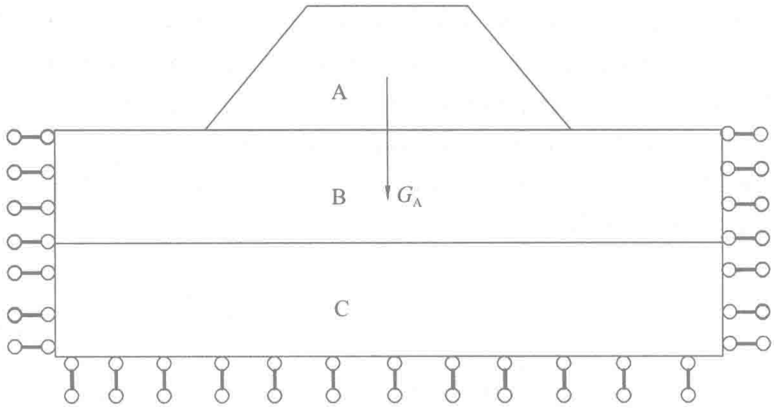


Fig.2　Embankment calculation model

3.2　Element Type and Grid Meshing

To the 2D finite element analysis, 6 and 15 node triangular elements are both suitable. By comparison, 15-node triangular element is a very accurate element that can get accurate calculation result. But it needs a larger computer memory, and the speed of calculation and operation are relatively slowly. For this case, 6-node triangular element can provide sufficient precision. So 6-node plane triangular element is employed in the paper. Grid meshing is according to default method.

3.3　Calculation Parameters

The filling soil parameters have significant influence on calculation results. Based on geological prospecting data of the embankment and the large-size indoor experiment data, the parameters are proposed as Table.1 shown.

Table.1　The calculation parameters proposed

soil name	constitutive model	unit weight γ (kN/m^3)	elastic modulus E(kPa)	poisson ratio μ	cohesion (kPa)	internal friction angle (°)	shear dilatancy (°)
stone	Mohr-Coulomb	23.0	1.58×10^5	0.24	25.0	43.0	0.0
clay	Mohr-Coulomb	19.3	2.0×10^3	0.32	15.3	17.6	0.0
silty clay	Mohr-Coulomb	21.3	2.0×10^4	0.30	2.0	28.0	28.0
strong weathering schist	Mohr-Coulomb	22.1	1.0×10^5	0.28	30.0	30.0	—
weakly weathering schist	Linear-Elastic	25.5	4.6×10^7	0.25	—	—	—

3.4　Simulation Method

The stage-filling process is simulated by the model step by step when each layer is finished, all of its material parameters and geometric model will be activated. This is step construction function of the software PLAXIS.

Construction step is practically the most important input load type. It allows closing or activation the load, block and the structure objection. By this method, geometric size and load settings can be modified. Closing doesn't mean deleting element of model, but stiffness (or conductivity, or other analytical characteristics) matrix multiplied by a small factor. By closing the unit load will be zero. The mass and energy of the closed element will not be included in the calculation results. Similarly activation element doesn't mean adding them to the model, but re-activating them. When modeling all elements must be generated, including the element will be activated or closed (shown as Fig.3) .

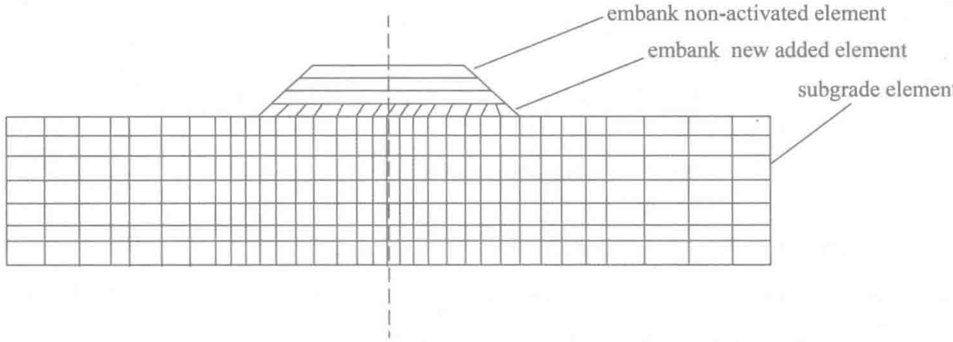


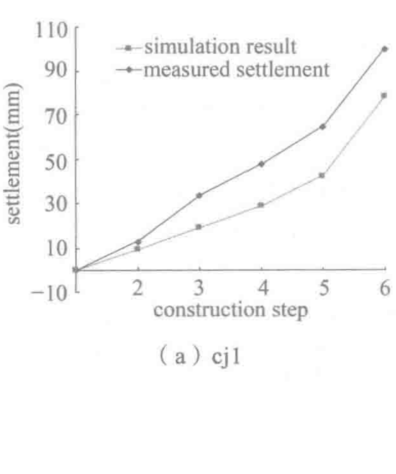
Fig.3 The activated element diagram of stage filling

This method can simulate the actual engineering problems, such as roadbed filling, digging tunnels, bridges and other constructions. In the practical construction, the height of every filling layer is 50 ~ 60 cm. If FEM calculation is strictly accordance with the practical height of each layer, the result is certainly more accurate. However, it also increases greatly the number of elements and calculation work. Generally, no more than ten loading step is adopted in FEM calculation.

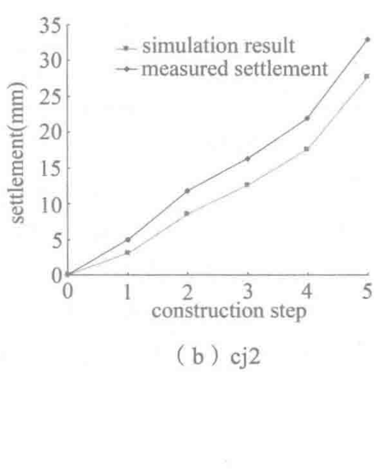
4 Analysis of Calculation Results

4.1 Comparison Simulation Result with Measured Data

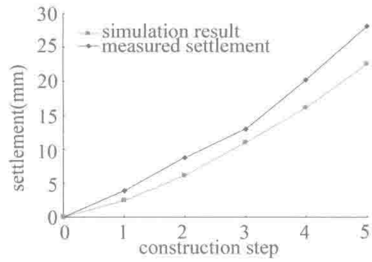
In the FEM calculation, the whole embankment is divided into five filling layers. Each layer has the same height. In this paper, the settlement of the location of three settlement plates is analyzed. The finite element simulation settlement results and measured settlement are shown in Fig.4. It demonstrates finite element calculation results are smaller than measured settlement.



(a) cj1



(b) cj2



（c）cj3

Fig.4　The settlement comparison chart of calculation results and measured results for settlement plates

At the location where settlement plates are buried, the total settlement of the three points are 78 mm, 33 mm and 23 mm.

Near the beginning of construction, the simulation result of cj1 is closer to the measured data, but the trend of the error gradually increases, the largest error ratio is 22%. This is because the settlement plate was broken during the construction.

The simulation results of cj2 are close to the measured results. During the construction process, the settlement observation plate is protected well.

The simulation settlement curve of cj3 and measured settlement curve have similar changing tendency. The simulation results slightly smaller than the measured results. So the FEM model can accurately simulate the stage filling process.

Fig.4 demonstrates that the settlement calculated by using FEM software is smaller than the actual measured settlement. Especially at the beginning of the construction, the difference between calculation settlement and measured settlement is very small. With the increasing of filling height, the difference becomes larger. This is because the stress level increasing with the construction processing. In addition, the parameters which obtained according to the geological data may be different from the practical value.

4.2　Displacement and Relative Shearing Strength

By finite element analysis, horizontal and vertical displacement cloud picture of the subgrade are shown in Fig.5 and Fig.6. Relative shearing stress cloud picture is shown in Fig. 7.

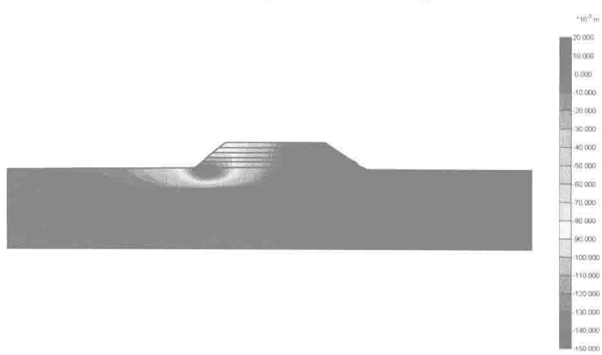


Fig.5　Horizontal displacement cloud picture

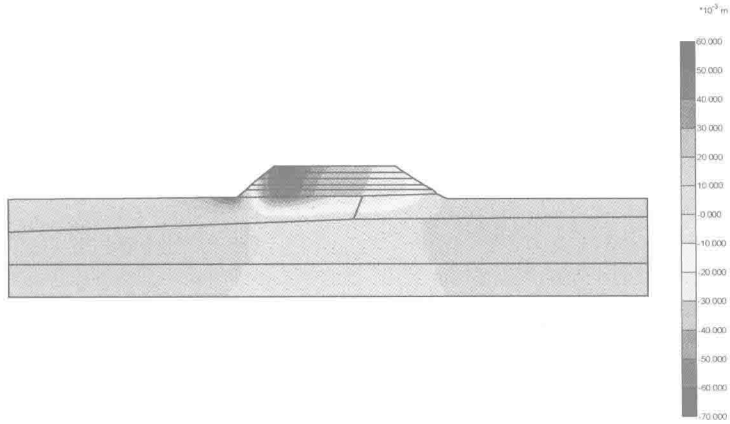


Fig.6　Vertical displacement cloud picture

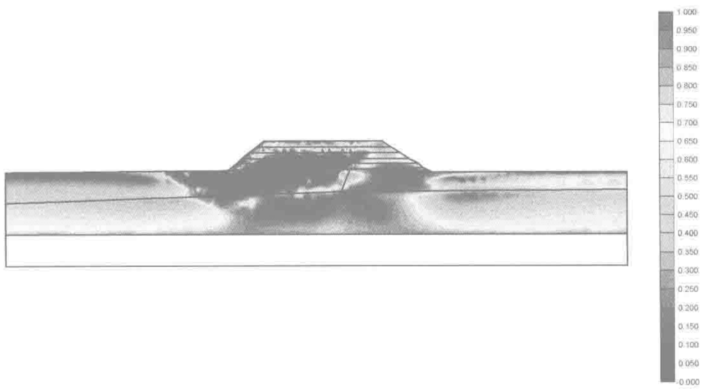


Fig.7 Relative shearing stress cloud picture

From Fig.5 and Fig.6, It can be seen that the horizontal and vertical displacements are larger, that is because the foundation soil under the left side of the embankment is deeper clay layer. The difference in geological conditions leads to large differences in settlement. So it is suggested that the thickness of filling soil of the left side should be increased to balance the settlement difference. At the same time, construction interval between each layer should be extended so that enough settlement takes place.

Affected by the mountain on the right side, the maximum shear stress appears at the central and left bottom of the embankment. However, shear failure does not appear. For an embankment on the slope foundation, the plastic zone firstly originates from the interface of the subgrade and the foundation. With the increasing of filling height, the area of plastic zone extends gradually to the top of embankment. The bottom of plastic zone is mainly distributed on the interface between embankment and subgrade.

FEM calculation results(Fig.8) show that the subgrade surface uplifts approximately 50 mm. Further uplifting doesn't stop until embankment filling is finished. The simulation results coincide with the actual situation.

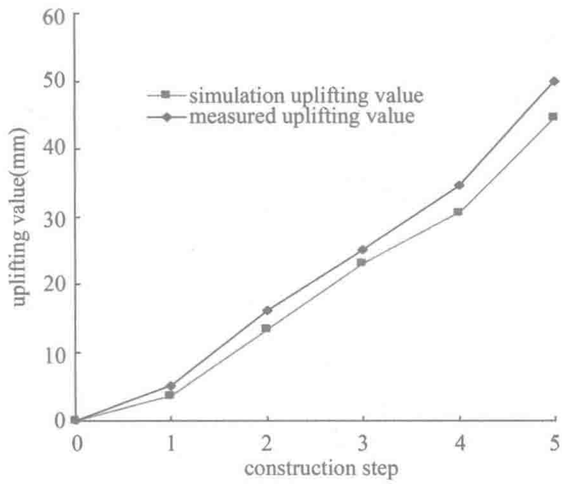


Fig.8　The vertical uplift of the side pile

5　Conclusion

The construction of layered buried embankment is well simulated by the software PLAXIS in the paper. The method is applied in the subgrade settlement calculation under embankment. The calculation result is compared with measured data and comparison result show that the simulation result is well consistent with the measured result. The error is allowed for the engineering construction, which proves the numerical simulation method is feasible.

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