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Evaluation on Stability and Improvement for the Expansive Soil Roadbed Filling

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Abstract

The improvement of expansive soil is one of the important contents in the field of engineering construction. On the basis of the test section of a highway, three kinds of modified schemes (lime soil, geotechnical fabric and geotechnical grille) were used to improve the embankment filling of expansive soil in the thesis. Through the field test and software analysis, it is found that the three schemes can meet the requirements of embankment stability, among them, the safety factor of the geotechnical material improvement test section is higher than that of the lime soil improvement test section, and the reinforcing effect is more remarkable. The geotechnical material modification method is a rapid, economical and effective technique for improving the expansive soil embankment, and the method is worth promoting vigorously.

Keywords

Expansive soil, Improvement, Monitoring, Stability.

1. Introduction

Expansive soil is a kind of typical soil, which is composed of a great deal of strong hydrophilicity clay minerals, such as montmorillonite and illite, it has much character, such as expansive construction, many cracks, strong expansive and contraction, intensity decadence [1-3]. Expansive soils are often mistaken as ideal materials for engineering filler because of the high strength and low compressibility under the state of hard plastic. However, when the water content of the expansive soil changes, the inner soil structure is damaged, which will decrease strength abruptly and increase compressibility. A series of quality problems and accidents are inevitable emergence when construction in expansive soil area, such as slope instability, ground uplift and cracking, etc., which bring immeasurable loss to engineering construction. Therefore, the modification of expansive soil has obvious social and economic benefits to improve the quality of engineering construction.

2. Engineering Background

NeiDeng highway passing through Neixiang county, Xichuan county and Dengzhou city in Henan province, the total length is 90.693km. The special rock soil is mainly expansive soil along the highway. The mineral composition is mainly montmorillonite and illite, with the character of fracture development, water swelling and drying shrinkage, this character can be changed extensively. The physical and mechanical indexes of the test section are as follow: the natural water content is between 15.8% and 31.4%, the average is 22.8%; the clay content is between 37.5% and 54.3%, the average is 43.1%; the liquid limit of expansive soil is between 40.6% and 54.1%; the free swelling ratio is between 38.5% and 51%, the average is 47.5%; the cation exchange capacity is between 7% and 20%, the average is 13.3%; the montmorillonite content is between 171.83mmol/kg and 364.85mmol/kg, the average is 223.3mmol/kg; the fast shear is between 16.4°and 34.1°, the average is 27.6°; the peak strength of residual shear is between 24.5°and 31.8°, the average is 28.28°; the average unconfined compressive strength during the expansion period is 5Kpa. According to the data of soil test, the expansive soil in this area is weak-medium expansion.

3. Modification Scheme of Embankment Filling

There are two main methods to modification the filling of embankment in the project: the chemical modification method and the structural modification method. The chemical modification is mainly to improve the chemical properties of soil by adding lime into the soil; the structural modification is mainly to lay geotechnical material in subgrade filling. There are two kinds of geotechnical materials: geotechnical fabric and geotechnical grille.

3.1 The Chemical Modification

When lime is added to the expansive soil, chemical reaction will occur between lime and soil. The strength of expansive soil is greatly improved, the swelling characteristics are improved obviously, and the permeability becomes smaller [4-7]. Lime improved by laying a layer of lime on three layers expansive soil. The lime soil (with thickness not less than 2 meters) covering on road shoulder slope to prevent the rainwater infiltration and the change of soil moisture. The lime content in soil was 6%, and the moisture content was controlled at 4% of the optimum moisture content. Lime improved soil is shown in Figure 1.

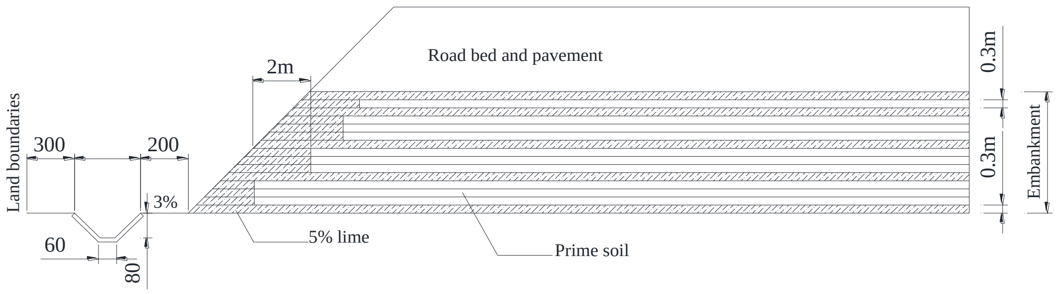

Fig.1. Lime Soil Embankment

3.2 The Structural Modification

(1) Geotechnical grille reinforced embankment. Geotechnical grille is a kind of polymer material with high tensile strength, the grille mesh to increase the friction between the geotechnical grille and soil, give full play to the characteristics of high tensile strength of geotechnical grille [8-9]. The geotechnical grille can enhance the stability of the embankment. In the structural modification of geotechnical grille, the tensile strength of geotechnical grille is more than 40KN/m^2, the width of geotechnical grille is more than 2m, laying a layer for every 50cm filler. The geotechnical grille reinforced embankment is shown in Figure 2.

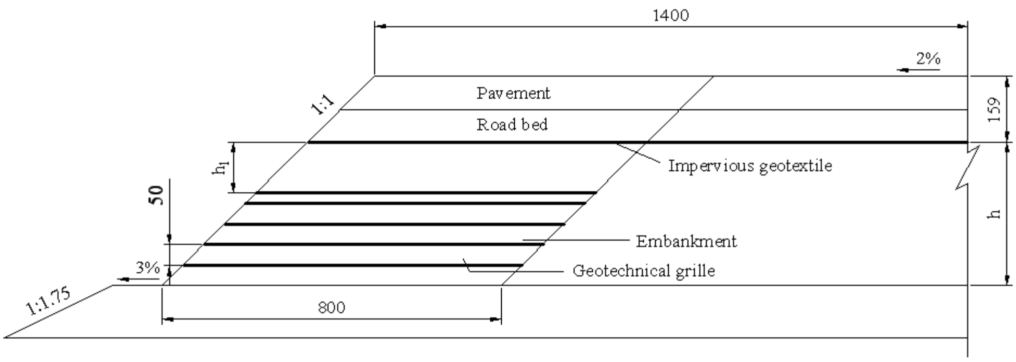

Fig.2. Geotechnical Grille Reinforced Embankment

(2) Geotechnical fabric reinforced embankment. Geotechnical fabric is a kind of polymer material, which has strong strength [10-15]. It can play the role of reinforcement in the embankment, and can also adjust the stress. The tensile strength of geotechnical fabric is not less

than 20KN/m^2, the width is not less than 4m. The strength of anti-seepage geotechnical fabric is greater than 40KN/m^2, the width is 4m, the bursting strength is more than 2KN/m^2, the permeability coefficient is less than 10-12cm, laying a layer for every 75cm filler. The geotechnical fabric reinforced embankment is shown in Figure 3.

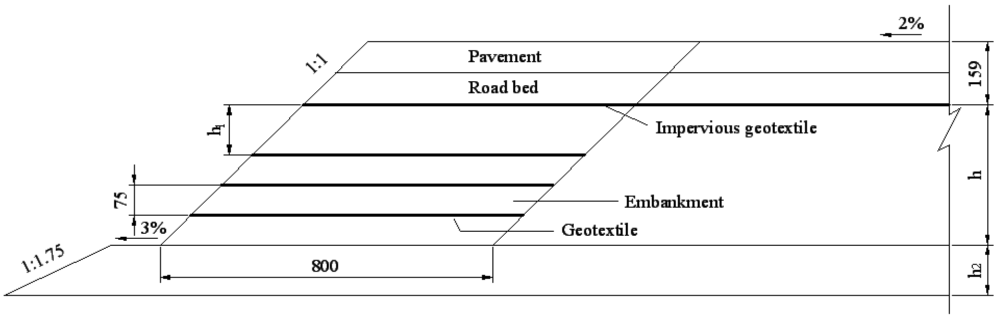

Fig.3. Geotechnical Fabric Reinforced Embankment

When laying geotextile materials, the soil surface should be smooth. The requirement of smoothness is: use a 3m long ruler to measure 4 positions, the height difference meet the requirement of not more than 15mm. Within the range of 8cm from geotextile, the maximum particle size of subgrade filler is not more than 5cm. Geotextile materials should be artificially stretched when laying, the geotechnical materials can be fixed with U nail, the spacing of U nail is about 1.0m. Lap seam staggered distance of geotechnical grille should be 0.5-1.5m, and lap seam staggered distance of geotechnical fabric should be 1-3m. Laying scene diagram of geotechnical grille as shown in Figure 4, laying scene diagram of geotechnical fabric as shown in Figure 5.

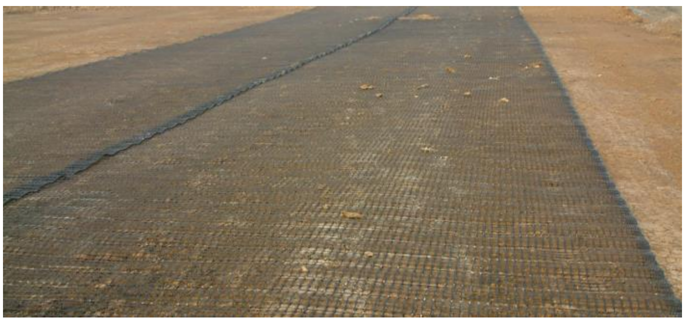

Fig.4. Laying Scene Diagram of Geotechnical Grille

Fig.5. Laying Scene Diagram of Geotechnical Fabric

4. Quality Monitoring and Evaluation of Modified Embankment

4.1 Layout of Monitoring System

In order to monitor the quality of embankment construction and analyze the stability effect of the expansive soil fill after reformation, monitoring systems are separate arranged in lime soil embankment, geotechnical grille reinforced embankment and geotechnical fabric reinforced embankment. The emphasis of monitoring is pavement deformation and the layered sedimentation value of embankment.

The deformation monitoring includes vertical settlement monitoring and horizontal side-tracking monitoring. Settlement monitoring is used to predict the settlement trend and provide reference for pavement construction. The settlement was measured by the layered settlement standards which were buried in soil after the completion of construction. The buried point should be chosen in the slope top with larger settlement and road center with smaller settlement. The horizontal side-tracking monitoring is used to observe the horizontal lateral displacement of the embankment. The horizontal displacement of embankment is measured by inclinometer tube, the inclinometer tube was buried in the position with relatively larger displacement so as to evaluate the stability of test embankment. The deformation monitoring arrangement is shown in Figure 6.

During the observation period without filling roadbed, settlement observations were performed every seven days for a time in the first month, after a month observations were performed every half month or a month for a time. During the observation period, if filling the road bed, observations were performed every a layer filling roadbed for a time, after the completion of filling roadbed, observations were performed every half month or a month for a time.

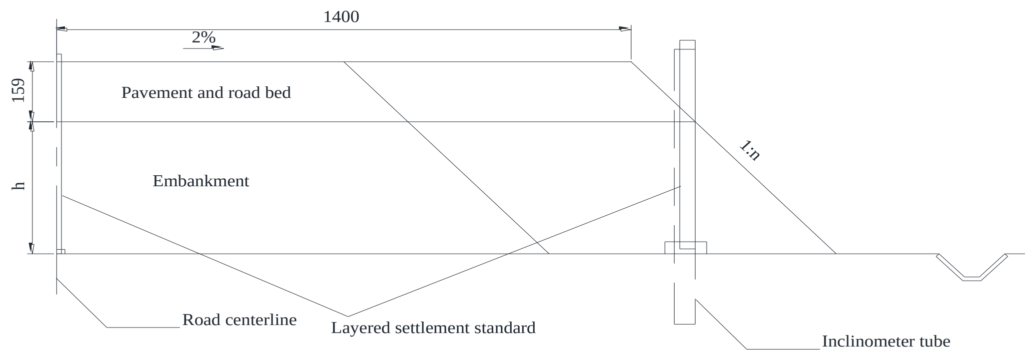

Fig.6. Deformation Monitoring Elevation Layout Drawing

4.2 Analysis of Deformation and Monitoring Data After Embankment Reconstruction

The settlement monitor is buried before paving, start reading from June 7th. Figure 7 and Figure 8 are the settlement monitoring graph of geotechnical grille reinforced road, the settlement monitor is embedded in the road shoulder in Figure 7, and the settlement monitor is embedded in the road center in Figure 8. Figure 9 and Figure 10 are the settlement monitoring graph of geotechnical fabric reinforced road, the settlement monitor is embedded in the road shoulder in Figure 9, and the settlement monitor is embedded in the road center in Figure 10. Figure 11 and Figure 12 are the settlement monitoring graph of lime reinforced road, the settlement monitor is embedded in the road shoulder in Figure 11, and the settlement monitor is embedded in the road center in Figure 12. Magnetic ring number from 1 to 3, the buried depth of magnetic ring as shown in Table 1.

Tab. 1. Magnetic Ring Buried Depth Data(unit: m)

Pipe number	1	2	3	4	5	6
Magnetic ring 1	1.8975	1.9675	1.9010	0.6750	0.1440	1.5500
Magnetic ring 2	3.8135	4.1850	4.3535			3.1680
Magnetic ring 3	6.3075	6.1975	5.1670			4.1865

The following conclusions can be drawn from the monitoring data in Figure 7-12: (1)After eliminating the individual deviation data, it can be seen that in the period of monitoring, the change of settlement is very small, generally in the range of a few millimeters, it can be determined that the settlement reaches to a stable state; (2) The settlement data of road shoulder changes between positive and negative, because the road shoulder is easily influenced by the external conditions, the deformation is more sensitive, but the deformation is small, it showed that the road shoulder is in a stable state; (3) In general, the settlement of embankment center is relatively small than the settlement of road shoulder, but in the test section, the settlement of embankment is relatively uniform because of geotechnical materials; (4)The settlement of embankment is mainly caused by consolidation of soil, but the embankment settlement increases, the main reason is soil expansion due to increase of water content. From the above analysis, it can be seen that the steep embankment reinforced with geotechnical material can still maintain stability, the settlement becomes uniform due to the geotechnical material.

At the same time, we should also see that the monitoring time is short, the amount of data is very small, and the data can not be analyzed in detailed.

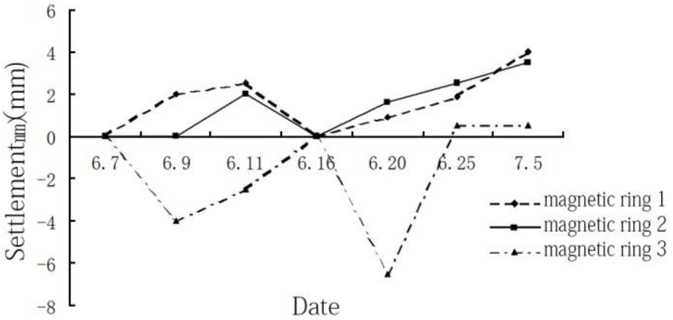

Fig.7. K243+900 Left Settlement

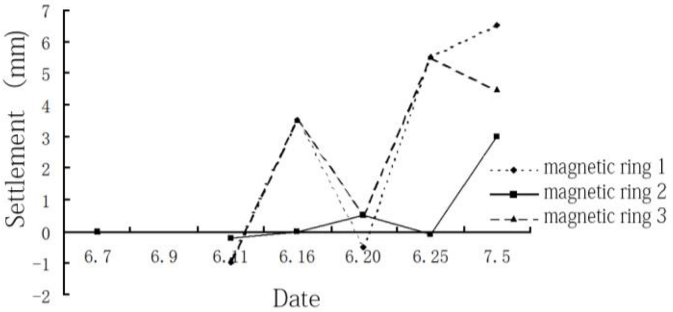

Fig.8. K243+900 Central Settlement

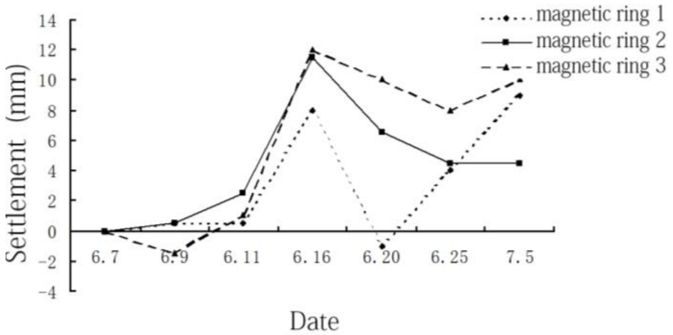

Fig.9. K243+800 Left Settlement

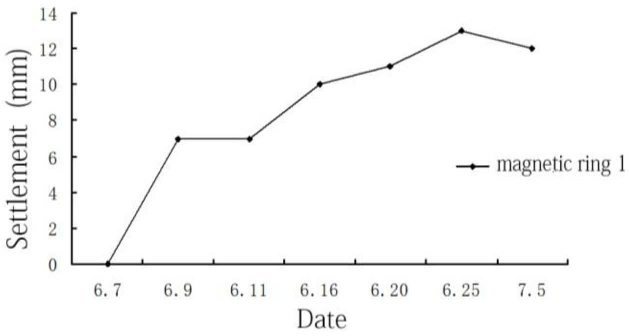

Fig.10. K243+800 Central Settlement

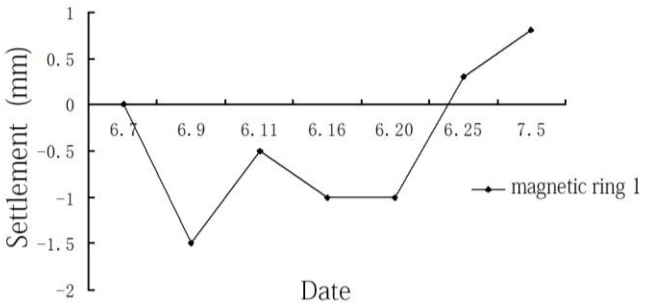

Fig.11. K243+700 Left Settlement

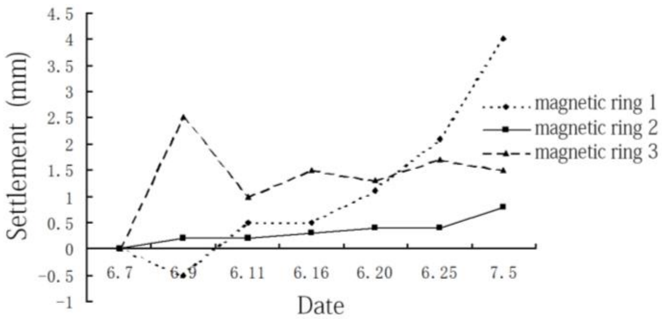

Fig.12. K243+700 Central Settlement

5. Embankment Stability of Calculation

5.1 Introduction of Geo-slope Software

In this paper, the geo-slope software is used to analyze the stability of expansive soil subgrade slope. The geo-slope software was developed by Calgary. Alberta company in Canada, it includes slope analysis and calculation module, seepage analysis module, rock stress and strain field analysis module, temperature field analysis module and seismic stress and strain field analysis module, every module can be used separately.

In this paper, the slope analysis and calculation module is used to calculate the safety of slope and embankment. The algorithm includes Ordinary method, Bishop method, Janbu method and GLE method.

5.2 Calculation and Result Analysis

(1) The test section of lime improved

In the lime improved expansive soil test section, the nature of pure soil as follows: c=20kpa, phi=15°; filling road bed and pavement with stable binder, the road bed and pavement were averaged according to some experience, then get the nature of road bed and pavement follows: c=10kpa, phi=40°.

The design slope ratio of embankment is 1:1.75, the attached load of pavement is about 60Kpa. The section of expansive soil slope is shown in Figure 13 and Figure 14, the filling height of highway is 6m, the top part of the road is pavement, and the height is about 80cm, the lower part of the pavement is road bed, the height of pavement and road bed is 160cm.

Calculate the safety of pure soil section by using the Geo-slope software. the safety factor value obtained by different algorithms as follow: the Ordinary method is 1.4288, the Bishop method is 1.541, the Janbu method is 1.5342. In general, the embankment stability meets the requirements.

The lime improved embankment section is shown in Figure 15 and Figure 16, the calculation of strength parameters (pavement, road bed and pure soil) is the same as that of the above examples, the lime nature is c=120kpa, phi=25°, the thickness of lime is 25cm, lime layer interval distribution in embankment. Calculate the safety of lime improved embankment section by using the geo-slope software. The safety factor obtained by different algorithms as follow: the GLE method is 1.578, the Ordinary method is 1.487, the Bishop method is 1.583, the Janbu method is 1.413.

When the lime layer is added in the embankment, the safety factor is increased, and the lime layer plays a role of waterproof permeability and prevents the spreading of crack in the embankment. Its significance is not only to improve the safety factor itself.

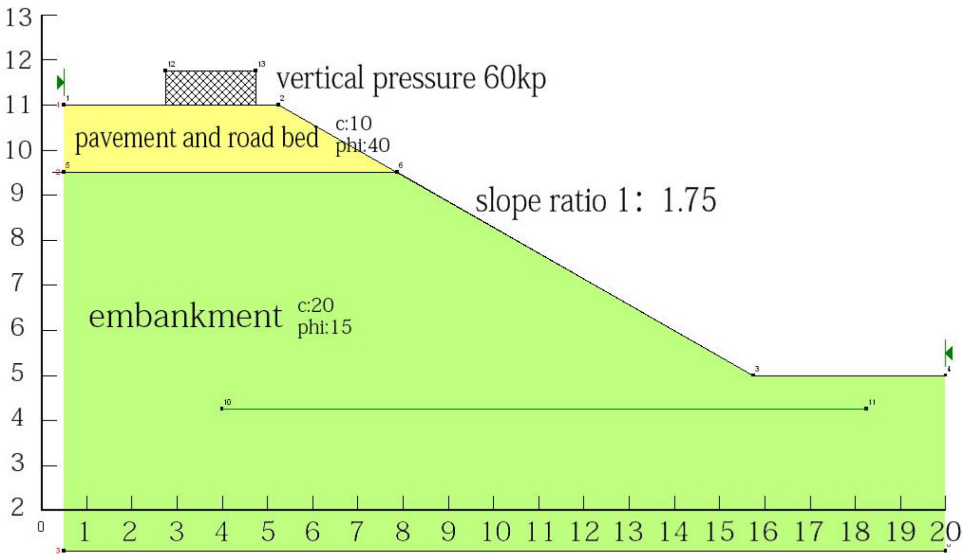

Fig.13. The Model of Pure Soil Embankment

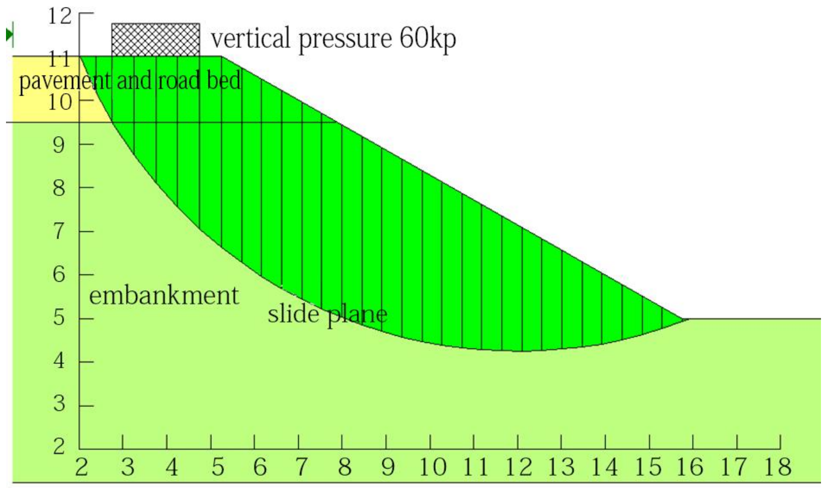

Fig.14. The Slide Plane Diagram of Pure Soil Embankment

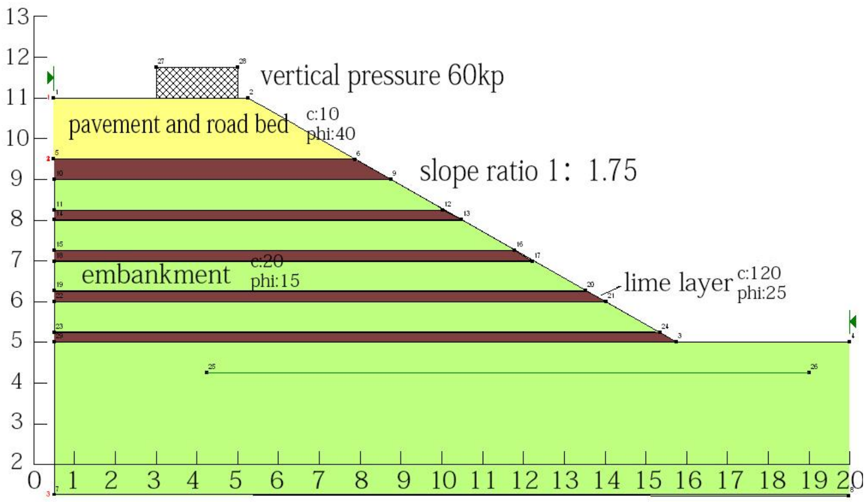

Fig.15. The Model of Lime Improved Embankment

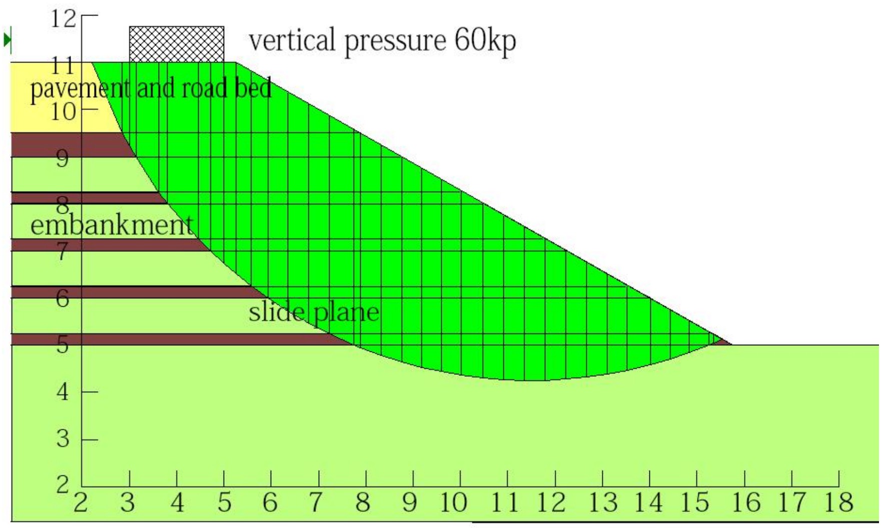

Fig.16. The Slide Plane Diagram of Lime Improved Embankment

(2) Geotechnical material improved section

Improvement of embankment with geotechnical material in the test section, the slope ration of embankment is 1:1. Firstly, the embankment without reinforcement is calculated (as shown in Figure 17 and Figure 18), the safety factor obtained by different algorithms as follow: the GLE method is 1.274, the Ordinary method is 1.223, the Bishop method is 1.283, the Janbu method is 1.138. Without considering the factors such as earthquake, soaking and cracking of expansive soil, etc, it can be regarded as stable, if these factors are considered, the safety factor is generally not up to requirements.

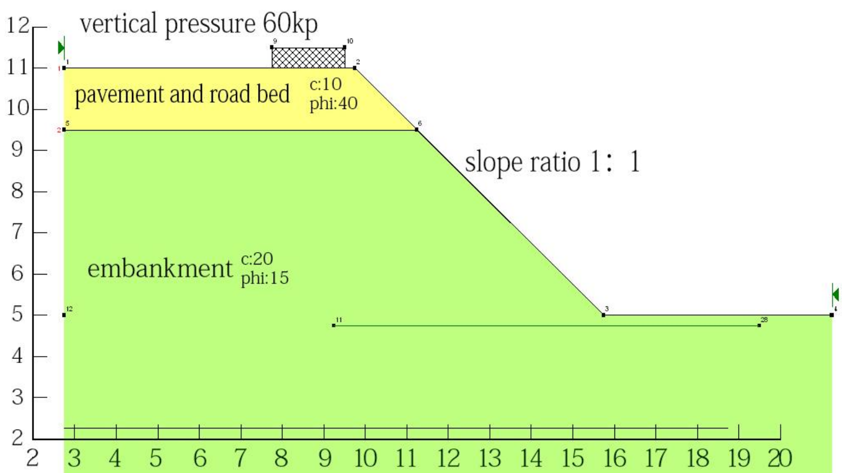

Fig.17. The Model Of Steep Embankment (slope ratio 1:1)

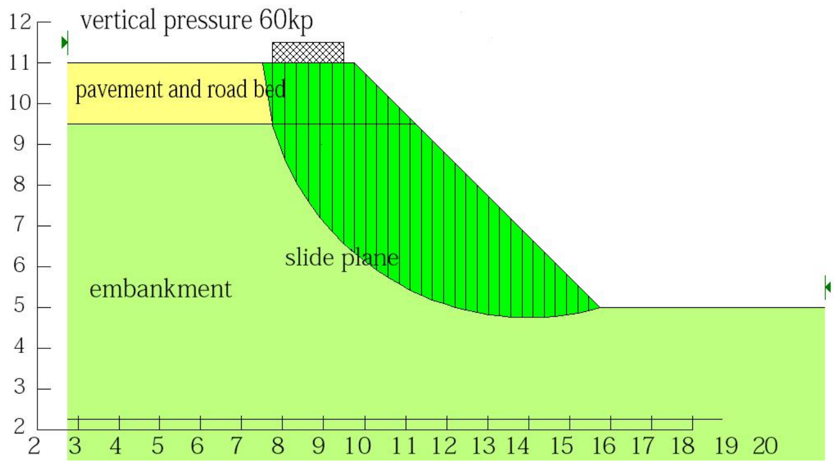

Fig.18. The Slide Plane Diagram of Steep Embankment (slope ratio 1:1)

There are two kinds of structural modification for embankment, one is geotechnical grille, and the other is geotechnical fabric. The tensile strength of the two materials is 50kpa, and the friction coefficient of geotechnical grille is bigger than that of geotechnical fabric. The geotechnical material is laid horizontally in the embankment, laying a layer every 0.5m, the upper and the lower floors are full spread, and the length of the geotechnical material in the middle is 8m (as shown in Figure 19 and Figure 20). Calculate the safety of geotechnical material improved embankment section by using the geo-slope software, the safety factor obtained by different algorithms as follow: the GLE method is 1.751, the Ordinary method is 1.632, the Bishop method is 1.753, the Janbu method is 1.588. Compared with the unimproved embankment, we can see that the safety factor increased by about 0.4-0.5.

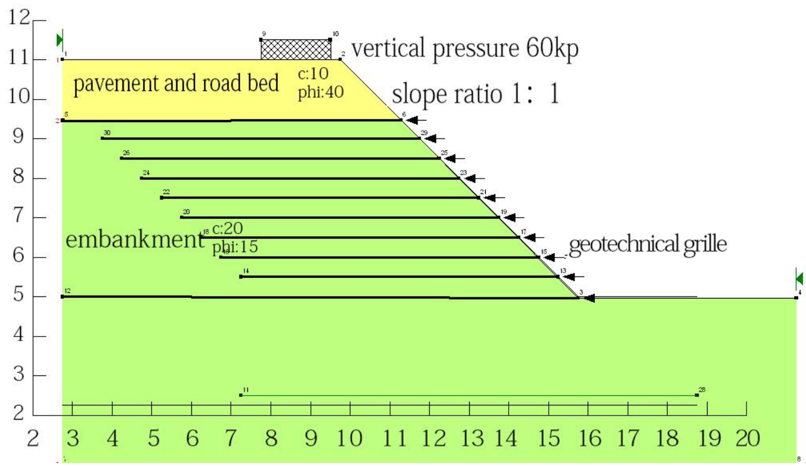

Fig.19. The Model of Geotechnical Grille Reinforced Embankment

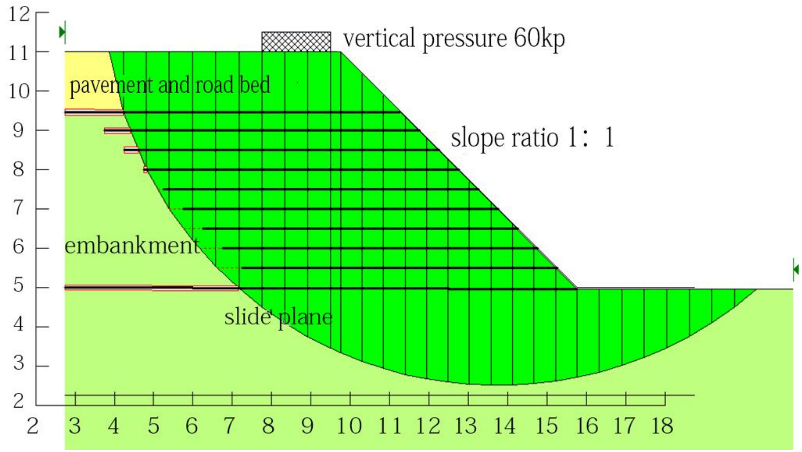

Fig.20. The Slide Plane Diagram of Geotechnical Grille Reinforced Embankment

Conclusion

It is necessary to modify the expansive soil when construction in expansive soil area. In this paper, three kinds of modification schemes(" lime improved ", " geotechnical grille reinforced" and "geotechnical fabric") of expansive soil are put forward, and through field monitoring and software's calculation, the deformation and stability of the three modified schemes are compared and analyzed, the results show that the three scheme can meet the stability criteria. Among them, the safety coefficient of geotechnical material improvement test section is higher than the lime soil improvement test section; the results show that the reinforced material is more significant to improve the expansive soil embankment. The geotechnical material modification method is a rapid, economical and effective technique for improving the expansive soil embankment, and is worth promoting vigorously.

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