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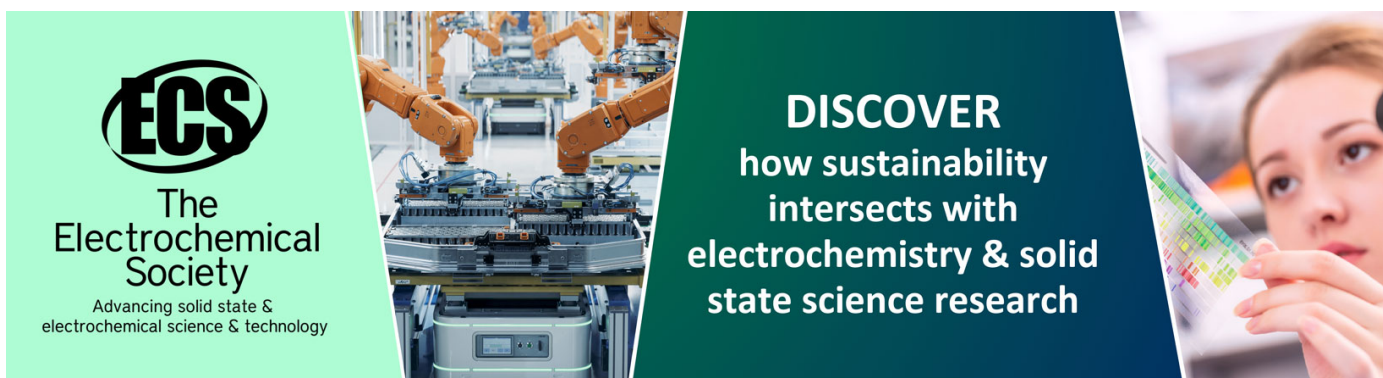
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Stability Analysis of Slope of Saline Soil Subgrade in Gravel Block Based on SLIDE

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Abstract: The saline soil roadbed in the cold region is affected by salt crystallization and migration, and the soil strength parameters change significantly. In order to determine the influence of salt migration on the stability of the roadbed under the conditions of laying gravel barriers of different thickness in the saline soil roadbed in cold regions. First, determine the type and physical parameters of saline soil in cold regions. Secondly, for the saline soil roadbed with different thickness of gravel partition in the base of the road, the slope software is used to analyze the stability of the subgrade slope, and the stability of the gravel partition is obtained. The effect of slope stability. The results show that when the gravel partition layer is set at the base of the road, the overall stability of the subgrade slope decreases with the increase of the thickness of the partition. When the thickness of the partition is more than 20cm, the dangerous sliding surface is transferred to the surface of the slope partition. The thickness of the partition layer increases, and the dangerous sliding surface remains stable, which provides reference data for the design of the saline soil roadbed in the cold region.

Key words: Saline soil roadbed; partition layer; slope stability.

1. Introduction

Saline soil refers to soil containing more than a certain amount of salt. It is broadly understood to include salt soil and alkaline soil, as well as the general term for different salinized and alkalized soils [1].

In the design of saline soil roadbed, the natural graded gravel soil is used as the capillary water partition layer, which is a commonly used method in road engineering at home and abroad. Under the condition of a certain thickness, it can not only block the capillary water, but also prevent the secondary salinization of the subgrade soil, and also increase the strength of the subgrade base.

The partition layer in the saline soil area can effectively block the rise of salt in the capillary water, and the partition layer refers to the partition layer with a certain thickness in a certain layer of the roadbed. Its fundamental purpose is to block the rise of capillary water and prevent moisture and salt from entering the upper part of the roadbed, thus avoiding damage to the roadbed or road surface. The partition type is made of geotextile (membrane) partition, aeolian sand or river sand partition, gravel



(broken) stone partition and tar sand, oil felt and other partitions. Geomembrane, tar sand and oil felt are impervious barriers, which can block the rise of lower capillary water and gaseous water. The gravel and aeolian sand are permeable partitions, which can block the rise of capillary water [2].

There are few research topics on the migration of water and salt in the saline soil area and the setting of the fault layer in the saline soil area. Only a small number of papers are related to the study of capillary water in subgrade soil, graded gravel and general coarse and fine grained soil. Dan Xinhui [3] studied the difference in capillary water rise height between brine and fresh water in the closed and open state of the graded gravel, which provided a theoretical basis for the thickness of the partition. Xue Ming, Zhu Weiwei, Jin Zhongzan [4] through the analysis of the route of salt intrusion into the roadbed, proposed corresponding partition measures, and built a test road to test its effect. The Institute of Northwest Research, the First Institute of Railways and the Institute of Railway Construction of the Ministry of Railways have conducted experimental research on the genesis, distribution, engineering characteristics, and hazards and treatment measures of the saline soil in the Chaerhan Lake area. At the same time, a lot of experiments have been carried out on capillary water and freezing depth in saline soil. Zhao Zhongdang [5] gave the method to determine the thickness when using natural graded gravel as the partition layer, including the card gauge method and the formula calculation method. Zhang Lihua [6] proposed to improve the roadbed and set up the partition layer to block the rise of capillary water and prevent moisture and salt from entering the upper part of the roadbed, thus avoiding damage to the roadbed or road surface. Kan Wenwu, Dong Lanfeng [7] proposed to improve the subgrade salinization and secondary salinization, using the method of improving the subgrade height, the water-permeable soil partition layer, the asphalt mortar (soil) partition layer, the geotextile material partition layer, and so on to dispose. Lu Gang, Lin Xueyu, Yao Jie [8] et al in order to prevent the migration of water and salinity in the roadbed in the saline soil area, the treatment methods such as improving the roadbed and providing the fault layer are given.

Since there is no calculation method for determining the thickness of the gravel barrier layer in the past, some sections are not designed to be thick enough to block the capillary water. In some places, the design is too thick, resulting in waste of materials, and sometimes even disagreements for the design of a reasonable thickness, resulting in disputes. Therefore, determining the thickness of the gravel soil partition is an urgent problem to be solved in the design of the subgrade in the saline soil section. To solve this problem, there are many factors involved, such as the soil of the stratum, the elevation of the groundwater level, the plasticity index of the cohesive soil, the strong rise of the capillary water of various soils, and the powder clay of the natural graded gravel soil. Content, blending thickness, maximum freezing depth (or maximum evaporation depth), etc.; It is an indispensable data to determine the thickness of the natural graded gravel soil partition. This paper selects the section of the Chag Expressway for testing. By using the slide software to analyze the stability of the subgrade slope, the stability is analyzed and compared, and the influence of the thickness of the gravel partition on the stability of the saline soil subgrade slope is obtained.

In the Slide software, the user can define one or several center radius search areas, and the software will automatically search for these areas and calculate the safety factor of all effective slip surfaces and give the minimum safety factor and slip surface. Users can manually define the search center circle radius search area, or let the software automatically obtain the center and radius search area, users can get reliable calculation results with very little time and settings. Slide software can search for arcs, non-arcs and composite slip surfaces according to the user's definition. At the same time, the software also supports the latest intelligent search method. The user only needs to define several parameters, and the software can search for dangerous slip surfaces. It greatly simplifies the workload of the user.

2. Engineering background

The climate data of Golmud City (2001-2015) was investigated, the data were collected from the China Meteorological Science Data Sharing Service Network.

Golmud is located in the southern part of Qinghai Province's western Mongolian Tibetan autonomous prefecture. Golmud city is located on the Golmud impact plain in the south-central part of the Qaidam Basin, with an average elevation of 2,780 meters.

The Golmud area belongs to the continental plateau climate, with little rain, windy and arid, long and cold winters, and cool and short summers. The Chag Expressway is one of the important sections of the "National Expressway Network" Liuyuan-Germu Expressway (G3011), and is also the western connecting expressway between Lianyungang to Khorgos and Beijing-Lhasa. It has important traffic strategic significance. The total length of the Chag Expressway is 80.052 kilometers. The whole line is constructed according to the standard of two-way four-lane expressway. The roadbed is 26 meters wide and the pavement structure is asphalt concrete. The designed driving speed is 100 kilometers per hour.

2.1. Analysis of precipitation and evaporation

Survey and analysis of monthly average precipitation and monthly average evaporation in the city from 1971 to 2000, The monthly average precipitation and monthly average evaporation are compared as shown in Fig. 1.

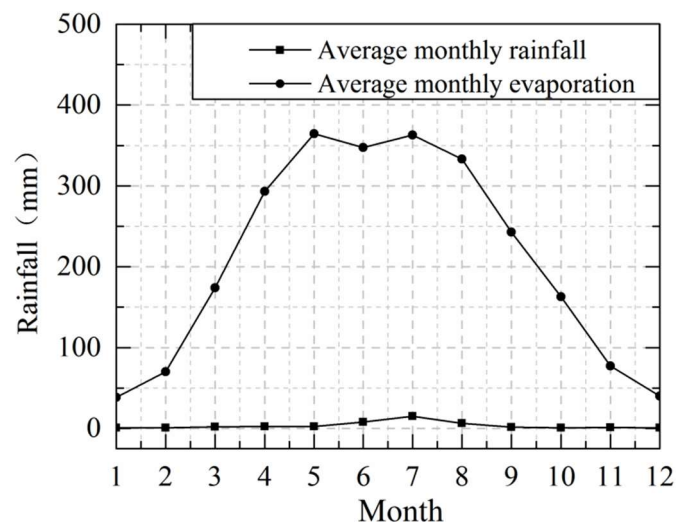


Fig. 1 Monthly average precipitation and monthly average evaporation of Golmud

According to the collected data, the average annual precipitation of Golmud is 42.2mm, and the annual average evaporation is 2504mm. It can be seen from Fig. 3.2 that the precipitation of Golmud is mainly concentrated from May to September, accounting for 87.4% of the total annual precipitation.

Formula based on drying index:

$$r = E_0 / P;$$

Where:

r — drought index;

E_0 — annual evaporation, mm;

P — annual precipitation, mm.

It can be calculated as the Golmud dry index $r \approx 59.3$. When $r < 1.0$, it means that the evaporation capacity of this area is less than the precipitation. The area is humid climate. When $r > 1.0$, the evaporation capacity exceeds the precipitation, indicating that the area is biased to drought. The greater r , that is, the more the evaporation capacity exceeds the precipitation, the more severe the drought. It can be seen that the climate of Golmud is extremely dry.

2.2. Analysis of temperature

As shown in Fig. 2, Golmud temperature reached its lowest value in January, with an average minimum temperature of -15.4°C , the highest temperature in July, and the average maximum temperature reached 24.7°C . In each month, the monthly average maximum temperature differs from the monthly average minimum temperature by about 14°C .

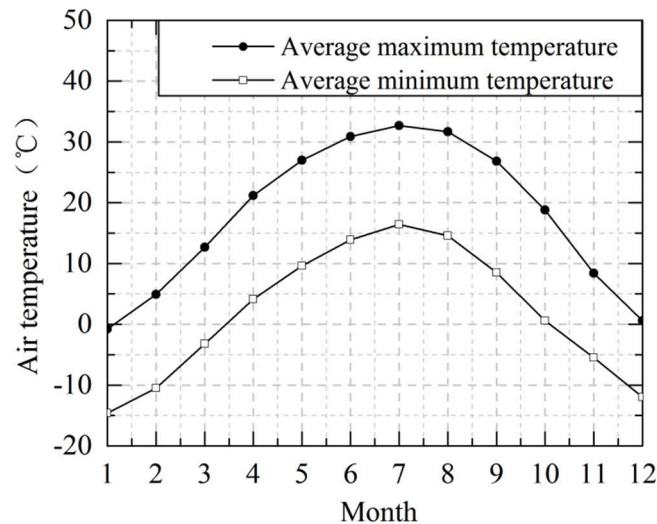


Fig. 2 Golmud annual average temperature

2.3. Analysis of dround temperature

The geothermal temperature of 0cm, 10cm, 20cm and 40cm underground from Golmud 2001 to 2015 was investigated and analyzed. The monthly temperature change is shown in Fig. 3.

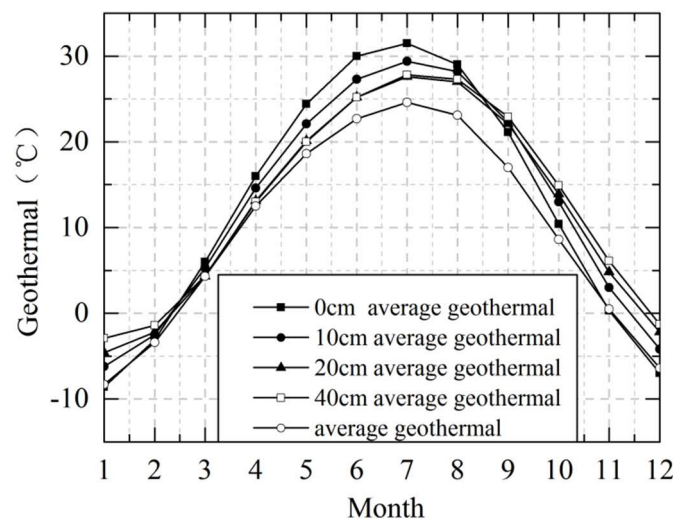


Fig. 3 Golmud ground temperature

It can be seen from Fig. 3 that the periodic variation of the ground temperature is basically the same as the temperature change, but the ground temperature is higher than the temperature, and the ground temperature at different depths also changes periodically with the temperature. However, the magnitude of the fluctuation of the fluctuation decreases with the increase of the depth, and the appearance of the

peak also lags with the increase of the depth. It can be seen from the existing data that the soil in Golmud City has the possibility of freezing the soil at a depth of more than 40 cm.

3. Analysis of test

3.1. Soil sample characteristics

In order to explore the stability of the subgrade slope in the Golmud area, the soil samples along the Chag Expressway were collected. Tables 1 and 2 list the basic parameters and ion content of the soil samples.

Table 1. Physical property parameters of saline soil

Soil grouping	proportion	Liquid limit (%)	Plastic limit (%)	Optimum water content (%)	Maximum dry density (g/cm ³)	saturation (%)
Soil sample	2.42	26.3	17.4	6.6	1.96	75.6

Table 2. Contents of different salinities in saline soil

Soil grouping	Salt content (% by weight)							Total salt content (%)
	CO ₃ ²⁻	HCO ₃ ⁻	Cl ⁻	SO ₄ ²⁻	Ca ²⁺	Mg ²⁺	total	
Soil sample	0.03	0.13	17.93	0.48	0.60	0.98	20.14	36.1

3.2. Test results

In cold regions with widely distributed saline soils, changes in volume and shear strength caused by temperature drop can have a significant impact on highway engineering. The following are the results of shear stress-strain relationship and shear strength parameters of saline soil during cooling.

The maximum shear strength of soil samples under different loads at different test temperatures was determined. According to the Mohr-Coulomb failure criterion, the relationship between cohesion and internal friction angle is obtained by linear regression, as shown in Fig. 4. It should be noted that the cohesion and internal friction angles are obtained under peak shear stress because the soil sample is not saturated and the strain rate is high, and drainage is not allowed during the shearing process [9-10].

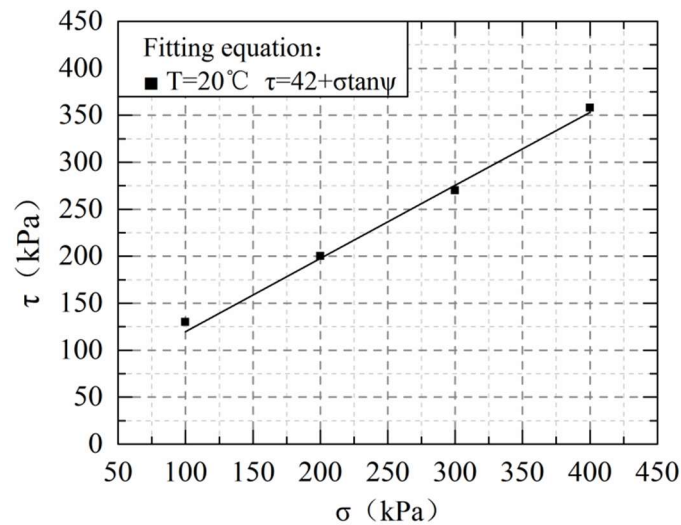


Fig. 4 Peak shear strength and blanketing pressure of HC-1 samples at different test temperatures

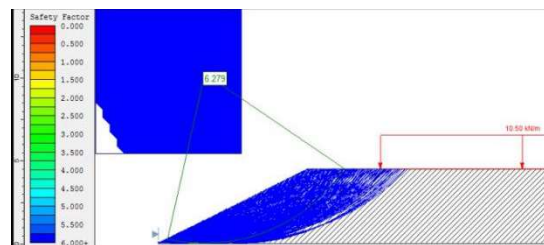
4. Stability analysis of subgrade slope with fault layer

Due to the use of the soil sample filled with the soil sample, the shape and position of the sliding surface are not determined. Manual calculation analysis and analysis using slope software will default the sliding surface from the foot of the slope. Such an analysis method cannot accurately find the location of the most dangerous sliding surface when analyzing the stability of subgrade slopes filled with various soil layers. Therefore, in the current engineering design calculations, the slide software is often used for auxiliary calculation. This article will use the slide software to analyze the saline soil roadbed slope where the gravel partition is set.

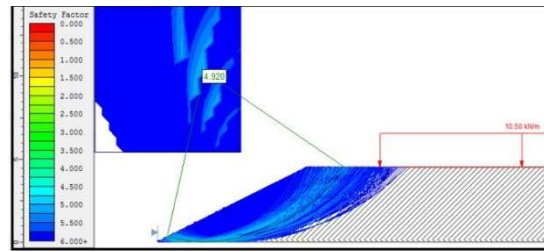
Taking the roadbed filled with soil samples as an example, when the gravel partitions of 20cm, 30cm, 40cm, 60cm and 80cm are respectively arranged at the base of the road, the stability of the subgrade slope is shown in Fig. 5 The engineering properties of the filler are shown in Table 3.

Table 3. Engineering properties of the filler

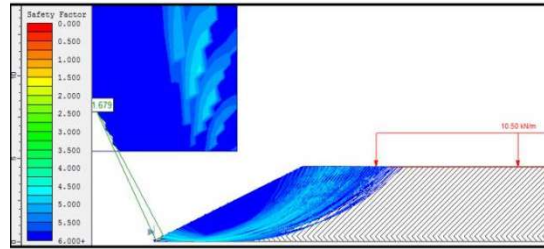
Soil sample	Cohesion C	Internal friction angle ϕ °	$\tan \phi$	Volume weight γ (kN/m ³)
	(kPa)			
Saline soil	42	37.89	0.778	19.21
Graded gravel	0	40	0.839	22



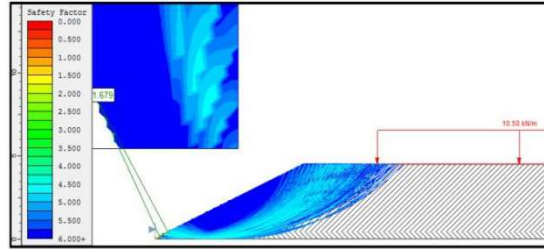
(1) Stability factor $K = 6.279$ when no gravel partition is provided



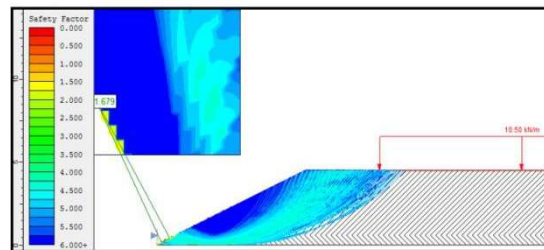
(2) Stability factor $K=4.920$ when setting 20cm thick gravel partition layer



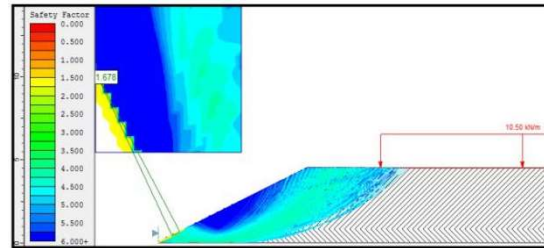
(3) Stability factor $K=1.679$ when setting 30cm thick gravel partition layer



(4) Stability factor $K=1.679$ when setting 40cm thick gravel partition layer



(5) Stability factor $K=1.679$ when setting 60cm thick gravel partition layer



(6) Stability factor $K=1.678$ when setting 80cm thick gravel partition layer

Fig. 5 Subgrade slope stability changes

According to Fig. 5, the change trend of the minimum K value when the gravel partition layers of 20 cm, 30 cm, 40 cm, 60 cm, and 80 cm thick are respectively disposed at the base of the road is as shown in Fig. 6.

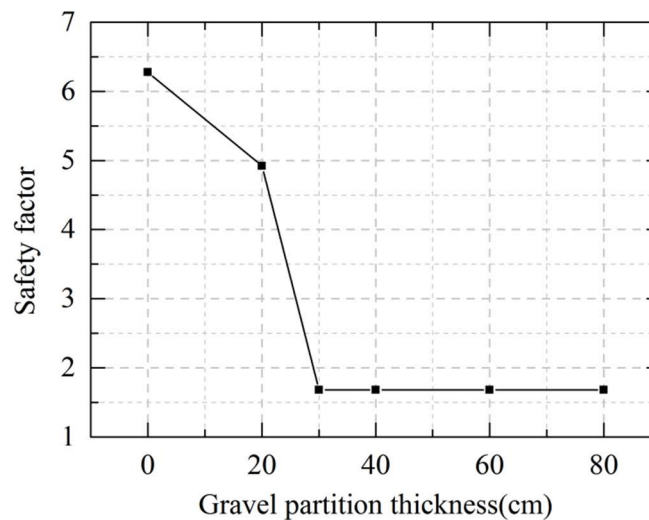


Fig. 6 Trend of roadbed stability coefficient K

It can be seen from Fig. 6 that when the gravel partition layer is arranged at the base of the road, the overall stability of the roadbed slope decreases significantly with the increase of the thickness of the partition layer. When the thickness of the barrier layer is more than 20cm, the dangerous sliding surface is transferred to the surface of the slope partition. As the thickness of the barrier increases, the dangerous sliding surface remains unchanged, and the minimum stability coefficient K remains at about 1.679. At this time, the stability of the subgrade slope can still meet the design requirements.

When it is necessary to set up a gravel partition during engineering design, we need to analyze the stability of the slope at the foot, and strengthen the slope according to the actual situation to prevent the surface of the slope from peeling off.

5. Conclusion

In this paper, the influence of salt migration on the stability of the roadbed is determined under the condition that the gravel soil subgrade in the cold area is laid with different thickness gravel barrier layers. First, determine the type and physical parameters of saline soil in cold regions. Secondly, for the saline soil roadbed with different thickness of gravel partition in the base of the road, the slope software is used to analyze the stability of the subgrade slope. By analyzing and comparing the stability, the influence of the thickness of the gravel partition on the stability of the saline soil roadbed slope is obtained, and the following conclusions are obtained:

(1) The migration of salt in the saline soil roadbed is affected by the comprehensive influence of water and temperature difference.

(2) When the gravel partition layer is installed at the base of the road, the migration of salt can be effectively reduced. As the thickness of the partition increases, the overall stability of the subgrade slope decreases significantly. When the thickness of the partition layer is more than 20cm, the dangerous sliding surface is transferred to the surface of the slope partition. With the increase of the thickness of the partition layer, the dangerous sliding surface remains unchanged, which provides reference data for the design of the saline soil roadbed in the cold area.

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