Analysis and Influence of Salt Content on Stability of Saline Soil Subgrade Slope

Yang Zhang¹,², Zhenpeng Qu¹,², Lixia Yang³

¹ Research and Development Center of Transport Industry of Technologies, Materials and Equipments of Highway Construction and Maintenance. (Gansu Road & Bridge Construction Group), Lanzhou 730030, China.
² School of Traffic and Transportation, Lanzhou Jiaotong University, Lanzhou 730070, China.
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Abstract. In order to determine the stability of the subgrade of the saline soil subgrade under different salt contents in the cold region. Two soil samples were selected to determine the salt content and mechanical parameters, and then the Slide software was used to analyze the stability of subgrade slope. The results show that the less the salt content, the greater the shear strength of the soil and the higher the stability of the subgrade slope.

Key words: Saline soil subgrade; salt content; slope stability; Slide software.

1. Introduction

In recent years, people’s production practices have become more closely linked to slope engineering, subgrade engineering using local saline soil as a roadbed filler in inland saline soil areas is increasing, then, due to the special mechanical properties of saline soil, the evolution of slope engineering problems has become increasingly prominent. In addition, the slope project has gradually developed a complete scientific theory after more than 200 years of continuous development and improvement from the initial simple calculation, involving many disciplines and fields, such as physics, engineering geology, engineering mathematics, mechanics, and engineering structures.

Many scholars have studied the mechanical properties of saline soils with different content types and salinity. Chen Xiaobai et al. [1] proposed the trend of unconfined strength of soil in heavy salt soil during repeated temperature rise and fall. Pharr [2] proposed the characteristics of unconfined compressive strength under salt-free ice and salt-bearing frozen sand under constant load conditions, although the time at which the two materials reach the damage varies greatly, the creep properties are very similar when the strain is less than 2%; Roman [3] proposed the effects of three different salts of NaCl, MgSO₄ and Na₂SO₄ on the creep deformation of soil; Brouchkov and Biggar [4] analyzed the bearing capacity of saline soil, and Brouchkov experimented with the bearing capacity of saline soil: The sea sedimentary saline soil containing Cl has the lowest bearing capacity, and carried out a series of tests on the bearing capacity of fine-grained saline soil with temperature and salt content; Biggar [5] conducted mechanical tests on pile foundations in various frozen saline soils and salt-bearing permafrost regions, the study yielded: the effect of salt makes the stress index in the stress-strain formula a variable value. Aksenov
[6] gives a reference value for some salt content, and summarizes the experimental research methods for salt-bearing frozen soil. Zhou Yongxiang, Pei Peiyu (2006) [7] the self-developed YZS curing agent was used to cure a clayey saline soil in the Golmud area of Qinghai Province, revealing the change of mechanical properties of the solidified soil after dry and wet cycles. From the above studies, it is not difficult to find that the strength characteristics of different types of saline soils are quite different.

It is necessary to study the influence of saline soil as a subgrade filler on the stability of slope. The limit equilibrium method is the most widely used method in the slope stability analysis method. In order to convert the static uncertainty problem into the static problem, some assumptions are made in the force analysis; Slope stability analysis can also be carried out through engineering geological survey, according to the actual situation of the site, establish different working condition models in the laboratory, carry out indoor test simulation, and compare the results obtained by the indoor test, multi-angle analysis, on this basis the analysis of the stability of the slope is completed, and this method is the limit analysis method; Later, with the development of computer, the numerical simulation method can also be used to analyze the slope stability. Through the finite element method, the numerical solution can be obtained efficiently and accurately, and the slope sliding body can be stressed. - strain (deformation) analysis. The limit equilibrium method, the limit analysis method and the finite element method each have their own development history and background, and their application is not the same.

With the rapid development of computer technology, fem has been applied in geotechnical engineering. In 1975, British scientists Zienkiewicz et al. [8] proposed in an example of a research paper that finite element method was used to calculate the very important ultimate load and safety factor in geotechnical engineering. In order to make the slope just in the failure state, the main strength parameters of soil were treated as follows: Cohesion c divided by the strength reduction coefficient, while the tangent value of the internal friction Angle also divided by the strength reduction coefficient, research shows: the difference between the calculated result by this method and the safety factor calculated by the limit equilibrium method is small. However, the numerical calculation method was not mature at that time, and the calculation precision was not high enough to solve large numerical models. Han and Leshchinsky[9] analyzed the safety factors and sliding surfaces of slope under different working conditions, respectively used the traditional limit equilibrium method and the strength reduction method based on finite element, and compared the results. It was found that the difference in safety factor obtained by the two methods is small, but the sliding surface is different, but the difference is not big. Song erxiang [10], a Chinese scholar, used the finite element method to solve the safety coefficient of geostucture, and calculated the safety coefficient of an earth dam in an example, and used Bishop method to solve the safety coefficient of earth dam in the example. Later, shang-yi zhao and ying-ren zheng, such as [11 ~ 15] to strength subtraction have done a lot of valuable research and Mohr - Coulomb failure criterion and other kinds of yield criterion analysis scientifically, strictly, and their mutual transformation is deduced the mathematical relationship, such as using Mohr - Coulomb area circle yield criterion to replace the commonly used Mohr - Coulomb failure criteria, the calculation results show that:There is little difference between the stability safety coefficient calculated by finite element method and limit equilibrium method.In short, although the finite element strength reduction method does not make any assumptions, the difficulty of solving the model is much higher than the traditional limit equilibrium method, and the calculation results of the safety coefficient are very similar. However, there is little research on the slope stability analysis and calculation of saline soil subgrade due to the change of salt content.

From what has been discussed above, due to salt in the saline soil type and salt content differences lead to the shear strength parameters are different, and the change difference of shear strength parameters of saline soil subgrade slope stability directly caused by the influence of different level, in this paper, according to two kinds of different types of salt and salt saline soil as subgrade filling, and carries on the shear strength test. Based on SLIDE software, finite element modeling of saline soil subgrade is carried out to calculate the safety coefficient of subgrade slope under different salt content, and the influence of saline soil subgrade on the stability of subgrade slope is summarized.
2. Engineering background
On May 15, 2017, Qinghai Province plans to build a section of the National Highway 215, which is part of the important passage connecting the three provinces of Gansu, Qinghai and Sichuan. The starting point of the highway is located in Yubei, Golmud City, Haixi Mongolian Tibetan Autonomous Prefecture, Qinghai Province. The terminal is located in Chaerhan, Golmud City. The total investment of the project is about 1.58 billion yuan. It is scheduled to be opened to traffic on September 30, 2019.

The highway is built using the technical standards of secondary roads and has two lanes in both directions. The design speed is 80 km/h, the new section has a width of 10.0 meters, use national highway G315 (K0+000~K31+600), the roadbed is 12.0 meters wide, using the development section of the Salt Lake Group (K161+210~K161+760), the width of the roadbed is 18.0 meters. The average elevation of the highway is 2,686 meters, the climate is dry, the winter temperature is low, the summer temperature is high and the sunshine time is long, the evaporation is much higher than the precipitation, and the soil content along the way is higher.

3. Physical properties and shear strength test

3.1. Basic physical properties of soil samples
In order to explore the stability of saline soil roadbed slope, soil sample of saline soil was collected. Table 1 and Table 2 listed the basic physical parameters and the salt content of the salt sample.

| Soil grouping | proportion | Liquid limit (%) | Plastic limit (%) | Optimum water content (%) | Maximum dry density (g/cm³) |
|---------------|------------|------------------|-------------------|--------------------------|----------------------------|
| CL-1          | 2.85       | 28.5             | 18.2              | 8.7                      | 1.83                       |
| CL-2          | 2.65       | 38.7             | 25.4              | 16.9                     | 1.77                       |

| Soil Grouping | CO₃²⁻ | HCO₃⁻ | Cl⁻ | SO₄²⁻ | Ca²⁺ | Mg²⁺ | total | Salt content (%) by weight | Total salt content (%) |
|---------------|-------|-------|-----|-------|------|------|-------|--------------------------|------------------------|
| CL-1          | 0.000 | 0.032 | 14.733 | 0.240 | 0.600 | 1.342 | 16.947 | 25.4                     |
| CL-2          | 0.000 | 0.006 | 3.373 | 1.488 | 0.700 | 0.244 | 5.811 | 11.9                     |

3.2. Shear strength test results
The maximum shear strength of soil samples under different loads at normal temperature was measured. According to the Mohr-Coulomb failure criterion, the relationship between cohesion and internal friction angle is obtained by linear regression, as shown in Fig. 1 and Fig. 2.
Fig. 1 Peak shear strength and blanket pressure of CL-1 specimen

Fig. 2 Peak shear strength and overburden pressure of CL-2 sample

Fig. 3 Comparison of shear strength between CL-1 and CL-2
It can be seen from Fig. 3 that there is a certain relationship between the shear strength and the salt content of the soil under the same blanket pressure, and the lower the salt content, the higher the shear strength of the soil.

4. Stability analysis of subgrade slope

The software slide v5.0 is a two-dimensional limit balance program for evaluating the stability or failure probability of rock or soil slope. The sliding surface can be either arc or non-arc. The program calculation method is based on vertical strip division limit equilibrium analysis (for example, Bishop, Janbu, etc.); For a given slope, you can specify a known sliding surface or the driver automatically searches for the sliding surface.

Table 3. Engineering properties of the filler

| Soil sample | Cohesion C (kPa) | Internal friction angle $\phi$ (°) | $\tan\phi$ | Bulk density $\gamma$ (kN/m$^3$) |
|-------------|------------------|-----------------------------------|------------|-------------------------------|
| CL-1        | 27.6             | 35.5                              | 0.71       | 17.93                         |
| CL-2        | 34.8             | 34.25                             | 0.68       | 17.35                         |

Fig. 4 Stability of slope of CL-1 saline soil roadbed

Fig. 5 Stability of slope of CL-2 saline soil roadbed

Analysis of Fig. 4 and Fig. 5 shows that the stability factor of the roadbed filled with YZ-1 filler is 5.25, and the stability factor of the roadbed filled with YZ-2 filler is 6.14. The salt content of YZ-1 soil sample is 25.4%, and the salt content of YZ-2 soil sample is 11.9%. With the decrease of soil sample salt, the stability factor of roadbed is improved. The trend of the change in K value is shown in Fig. 6.
5. Conclusion
This paper determines the effect of different salinity on the stability of saline soil roadbed in cold regions. First, determine the salt content and mechanical parameters of saline soil in cold regions. By using Slide software to analyze the stability of subgrade slope, the stability is analyzed and compared, and the influence of soil salinity on the stability of saline soil roadbed slope is obtained. The conclusions are as follows:
(1) As the salt content decreases, the shear strength of the soil increases;
(2) The stability of the saline soil roadbed slope is closely related to the soil salt content. As the soil salt content decreases, the stability factor of the subgrade slope increases.

Acknowledgements
The authors gratefully acknowledge the financial support provided by Opening Foundation of Research and Development Center of Transport Industry of Technologies, Materials and Equipments of Highway Construction and Maintenance. (Gansu Road & Bridge Construction Group) (No. GLKF201803).

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