

Effect of different replacement depth on slope stability of roadbed

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Abstract: Combined with the engineering example of Sanyangchuan tunnel and lead project in Tianshui City, firstly, the cement improved soil and lime improved soil with better mechanical properties were selected by experiment. Secondly, based on Geostudio software, a numerical calculation model is established to analyze the influence of different replacement materials and different replacement depths on the stability of the roadbed slope for different replacement ranges.

Keywords: Roadbed slope; Improved soil; Replacement filling method.

1. Introduction

The stability of the slope of the roadbed is the key to the quality of the whole road construction, and whether its structure and quality are stable and qualified plays a decisive role in the whole project. There is a soft soil geographical construction foundation, low bearing capacity, not easy to construct, and often occur uneven settlement phenomenon, to a certain extent to reduce the length of the road, the construction of the road in the soft soil foundation, easy to trigger a variety of road hazards. [1] The standard definition of soft ground in the industry is a weak soil layer with low strength and relatively high compression, small permeability, and the presence of certain organic materials in these soils. In highway design and construction, the formation of soft ground is mainly clay and powder soil with more fine particles, which will lead to settlement if the water table rises or the stability of the building is insufficient. [2-3] The characteristics of soft soil roadbed are divided into the following points: First, the soil is loose, and the clay and powder soil contains more fine particles. Secondly, it has large voids, high water content and high compressibility. Due to the above two characteristics, resulting in the construction of road and bridge soft ground strength and stiffness are too low and prone to uneven settlement phenomenon, has become one of the difficulties in the construction of buildings. If under construction or after the completion of the geological influence, easy to trigger the foundation subsidence and collapse of the problem, more serious will also be a threat to the personal safety of construction personnel.

The replacement method is widely used in highway projects and has many advantages, the most important being that it can strengthen the roadbed and improve the

construction quality of the whole project. The replacement method is also called the soil replacement method. The so-called replacement method refers to the reinforcement of the soft foundation of the highway. The specific process of the replacement method is to use a combination of manual and mechanical equipment to clean up the weak soil layer in the roadbed, and then use solid materials for filling and compaction, usually using hard soil and stones for filling in layers, thus enhancing the bearing capacity of the roadbed. Most of the time, natural gravels and flakes are used to fill the roadbeds because they are easy to find and relatively cost effective. [4-8] However, in determining the depth of the replacement fill, due to many influencing factors, it is often based on empirical method and lacks a quantitative calculation basis. According to the relevant literature, the quantitative calculation methods include the roadbed load working area method, the foundation bearing capacity method, etc. [9]

In this paper, we firstly compare the sexual mechanics experiments of cement and lime with different dosing amounts to select the suitable dosing materials, and then conduct numerical simulation based on Geostudio software to simulate and calculate the influence of different replacement materials and different replacement depths on the stability of roadbed slope.

2. Project Background

2.1 Geographical location and traffic conditions

Tianshui Sanyangchuan tunnel and lead project is located in Tianshui City, Maiji District, the tunnel inlet is located in Dengjiazhuang, before connecting to the northern end of the Tianxiu Bridge ramp, and through the ramp to

Chengji Avenue; tunnel exit is located in Qiaohe New Village, through the interchange and Magan Highway connection, the tunnel import and export end are close to the existing road, convenient traffic.

2.2 Meteorology

Tianshui City is located in the northern temperate zone and has a semi-arid continental climate. The natural area is divided into the arid zone in the Yang Mountain in the north, the river valley in the middle and the humid zone in the shallow mountains in the south. The general climatic characteristics of Tianshui are: rapid warming in spring; no scorching heat in summer; continuous rain in autumn; and no severe cold in winter. The climate is mild, with four distinct seasons, sufficient sunshine and moderate precipitation. According to the weather observation data of Tianshui weather station, the multi-year average temperature of Tianshui is 10.9 °C, the extreme maximum temperature is 38.3 °C, the extreme minimum temperature is -19.2 °C, and the coldest monthly average temperature is -2 °C; the multi-year average precipitation is 580.0mm, and the highest record since the historical data was recorded in 2003 was 810mm. The distribution of precipitation is uneven, mainly concentrated in July-September, accounting for about 65% of the annual precipitation. According to the meteorological data of Qinzhou District, the maximum precipitation in the district is 286.6mm in a row, 113mm in a day and 57.3mm in an hour.

July-September, which corresponds to the period of concentrated precipitation, is also the period of frequent occurrence of landslide, landslide and debris flow, accounting for 70%, 80% and 90% of the total frequency respectively. The average annual precipitation day is 99 days.

The average maximum evaporation is 190.6mm (August); the average minimum is 34.0mm (January); the average annual evaporation is 1314.9mm. The maximum annual snow thickness is 15cm, the maximum permafrost depth is 61cm, and the prevailing wind direction is east.

2.3 Geomorphology

The project traverses the valley area of the river through the river, the north mountain of the river through the loess mount area to the south bank of the Wei River, the geomorphology is erosion accumulation valley landform and denudation structure hilly landform, the topography is undulating, the relative height difference is 200 ~ 400m.

(1) Erosion and accumulation valley

It is distributed at both ends of the project area, and the starting point of the line is located in the area of the valley step of the river by the river, and the end of the line is located in the area of the valley step of the river by the Wei River. Due to the erosion of water and artificial transformation, the form of the order surface has been unclear, and it is actually close to the foot of the loess hills. The Weihe River valley is a long east-west spreading valley with large width changes, and the Weihe River valley at the end of the project area is open, with a width

of 1 km. The river floodplain and terrace landforms in the valley are typical and open.

(2) Stripping structure hilly landform

The hills are distributed in the middle of the project area and are loess hills, with the beams extending from east to west, elevation 1112~1534m, relative height difference 422m, slope gradient 10~35°. The base of the mountain is Neoproterozoic mudstone and Precambrian granite gneiss, overlain by the Fourth Series loess. The main characteristics are that the top of the mountain is beam-shaped, the top is narrower, the slope of the beam is slope gully development, cut deeper, the valley is mostly "V" valley, and the local gully slope is upright. The area is a landslide and debris flow development area, and geological hazards are very developed.

3. Mechanical properties of the modified soil

The original soil of the roadbed slope is loess, which is a non-saline soil, and its physical properties are shown in Table 1.

Table 1 Physical properties of loess

Liquid limit/ %	Plastic limit/ %	Plasticity Index	Maximum dry density/ (g/cm ³)	Optimum moisture content/ %
29.2	19.8	9.4	1.880	14.3

3.1 Cement improved soil

The cement is 32.5 grade ordinary silicate cement, and the physical and mechanical indexes are shown in Table 2.

Table 2 Physical and mechanical indexes of ordinary silicate cement

Fineness	Burnt loss	Adequacy	Coagulation time		Compressive strength/MPa		Flexural strength/MPa	
			First condensation	Final condensation	3d	28d	3d	28d
≤ 10%	≤ 5.0%	Qualified	≥ 45min	≤ 10h	11.0	32.5	2.5	5.5

The cement was mixed into the loess at 3%, 5%, 7% and 9%, respectively, and heavy compaction tests and liquid-plastic limit tests were conducted. The mechanical properties of the cement-improved soil selected by comparing the experimental results with the 9% admixture are as follows.

Table 3 Compaction test and liquid-plastic limit test results

Soil sample	Liquid limit /%	Plastic limit /%	Plasticity Index	Maximum dry density (g/cm ³)	Optimum moisture content/%	Dry Density y/(g/cm ³)	Dry heaviness (kN/m ³)
9% hydro mulch	39.5	25.8	13.7	1.900	14.3	1.805	17.689

Table 4 Unconsolidated undrained triaxial shear test results

Soil sample	Compaction/%	Age of maintenance/d	$\varphi/(\text{°})$	c / (kPa)
9% hydromulch	95	28	44.7	553

3.2 Lime amended soil

The lime was made of Class II calcareous quicklime, and the quicklime was made of quicklime with its own dissipation, and the physical and mechanical indexes are shown in Table 5.

Table 5 Lime physical and mechanical indexes

Effective calcium plus magnesium oxide content	Water content	Sieve allowance of 0.17mm square hole sieve	Sieve allowance of 0.125mm square hole sieve
$\geq 60\%$	$\leq 4\%$	$\leq 1\%$	$\leq 20\%$

Lime was mixed into the loess at 3%, 5%, 7% and 9%, respectively, and heavy compaction tests and liquid-plastic limit tests were conducted. The mechanical properties of the cement-amended soils selected by comparing the experimental results with the 5% admixture are as follows.

Table 6 Compaction test and boundary moisture content test results

Soil sample	Liquid limit /%	Plastic limit /%	Plasticity Index	Maximum dry density / (g/cm ³)	Optimum moisture content /%	Dry Density / (g/cm ³)	Dry heaviness / (kN/m ³)
5% lime soil	36.1	22.5	13.6	1.772	15.9	1.683	16.497

Table 7 Unconsolidated undrained triaxial shear test results

Soil sample	Compaction/%	Age of maintenance/d	$\varphi/(\text{°})$	c / (kPa)
5% lime soil	95	28	36.9	222

4. Numerical simulation model

The numerical simulation model based on the roadbed slope of the project is established as follows.

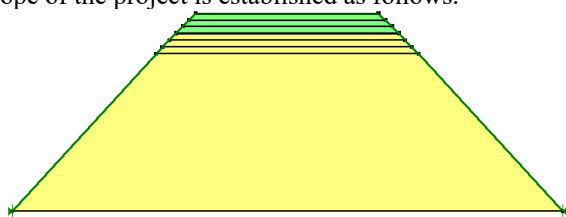


Fig.1 Numerical simulation model

After inputting the soil properties of the roadbed slope, six areas were set up at 0.5m intervals in the range of 0.5-3m to analyze the changes of the stability of the roadbed slope when using 9% dosed cement improved soil and 5%

dosed lime improved soil with the replacement range of 0.5m, 1m, 1.5m, 2m, 2.5m and 3m respectively.

The variation curve of the safety factor with the range of the replacement fill when using 9% blended cement improved soil is obtained as follows.

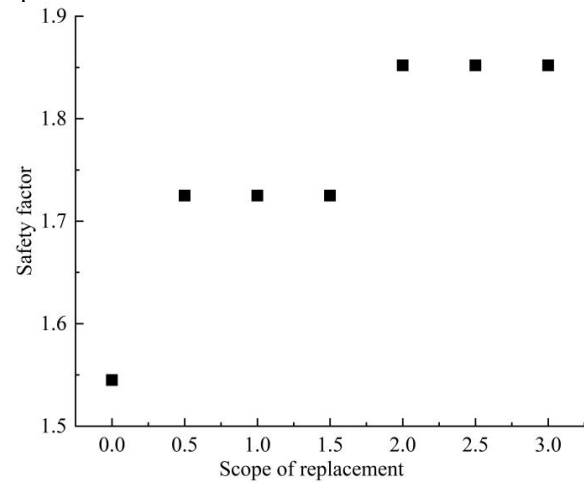


Fig. 2 Variation curve of safety factor (9% blended cement improved soil)

Analyzing the above figure, it can be seen that 9% cementitious improved soil can effectively improve the safety coefficient of the roadbed slope, and the safety coefficient of the roadbed slope is 1.725 when the replacement range is 0.5-1.5m, and the safety coefficient of the roadbed slope is 1.852 when the replacement range is 2-3m. Considering the economic benefits and road safety, when using 9% cementitious improved soil to replace the roadbed, the replacement range of 0.5m is a better quality choice.

The variation curve of the safety factor with the range of replacement fill when using 5% lime amended soil is obtained as follows.

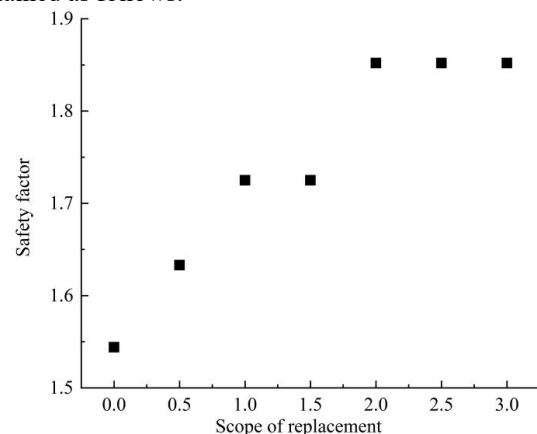


Fig.3 Variation curve of safety factor (5% lime amended soil)

Analyzing the above figure, it can be seen that 5% lime amended soil can effectively improve the safety coefficient of roadbed slope, and the safety coefficient of roadbed slope is 1.633 when the replacement range is 0.5m, 1.725 when the replacement range is 1-1.5m, and 1.852 when the replacement range is 2-3m. Considering the economic benefits and road safety, it is better to use 5% lime amended soil when the replacement range is 1m. In consideration of economic benefits and road safety, when using 5% lime improved soil for roadbed

replacement, the replacement range of 1m is a better choice.

5. Conclusions

Through the combination of indoor experiments, the cement improved soil and lime improved soil with better mechanical properties were selected, and the numerical calculation model was established based on Geostudio software to analyze the influence of different replacement materials and different replacement depths on the stability of the slope of the roadbed, and the following conclusions were drawn.

(1) In the comparison of the performance of improved soil with different doping amounts, 9% cement improved soil and 5% lime improved soil have better mechanical properties than other improved soils, and are more suitable as improved soil for roadbed slope replacement.

(2) Both 9% cement-improved soil and 5% lime improved soil can effectively improve the stability of the slope of the roadbed, and the improvement performance of both of them is similar in the numerical simulation results.

(3) The safety coefficient of the slope of the roadbed changes when the 9% cement-improved soil is replaced by 0.5m and 2m, and considering the economic and safety factors, the replacement range of 0.5m is a more economic and safe choice.

(4) When 5% lime improved soil is used to fill the slope of the roadbed, the safety coefficient of the slope of the roadbed changes when the range of replacement is 0.5m, 1m, 2m, and the range of replacement is 1m is a more economical and safe choice.

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