Study on Soil Hydrological Characteristics of Highway Spoil Disposal Site in Loess Region

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Abstract: Due to complex climates, geological conditions and landform types, the ecological environment in the western region of China is very fragile. Thanks to the continuous large-scale construction of highway transportation infrastructure over the years, the social transport services are satisfactorily offered in the western region, but also some negative impacts on the ecological environment in the western region are accompanied, especially a large impact on the land resources in extreme scarce in the western and weak soil & water conservation in loess region. The western loess region faces low land bearing capacity, fragile ecological environment and severe soil & water erosion. Restricted by its own conditions of the spoil disposal site, in the case of lack of rainfall and loose soil, it is very important for later restoration to accurately learn the hydrological characteristics of the spoil disposal site.

1. Slag characteristics of spoil disposal site in loess region

1.1. Pure soil disposal site
Most of the earth and stone in pure soil disposal sites are deep soils, which are basically unaffected by human activities such as farming and afforestation, and the soil maturation is low. Therefore, the pure soil disposal site is lack of organic matter and nutrients, and due to the rolling by transport vehicles and construction machineries, the soil granular structure is destroyed, the porosity is reduced, and the water holding performance and physical properties are degraded, which is not conducive to plant growth and development.

1.2. Earth-rock mixed disposal site
The waste materials in the earth-rock mixed disposal site are earthwork and stonework excavated in the construction, and the proportion of the two are basically equal or it is dominated by earthwork. In this study, the earth-rock mixed disposal site is defined as a spoil disposal site with an earthwork proportion of not less than 50% of the total spoil, especially the content of earthwork in the surface material composition of the disposal site.

2. Analysis on soil hydrological characteristics in spoil disposal site

2.1. Overview of the test area
The test area is located in the 8th bid section of Qing Lan highway (35°37´N, 109°38E´) in the south of Fuxian County, Yan’an City. In terms of landform, the area is loess gully area, with an average altitude of 1120m. It belongs to semi-arid temperate climate zone, with an average annual precipitation of 569 mm. The precipitation is unevenly distributed throughout the year, and mainly in summer. The test area is a spoil disposal site formed by wastes in highway construction. According to the condition of the
underlying surface, the test area can be divided into two types: loose earthwork and spoil disposal site construction roads. Loose earthwork is the wastes produced by highway construction, with a small bulk density and a large slope (the maximum slope can reach 78%); while the spoil disposal site construction roads has a large bulk density, but the slope is relatively gentle.

2.2. Test method
(1) Determination of soil bulk density and mechanical composition
Given the conditions of the above underlying surface, the soil bulk densities of the top layer (0-5cm), the middle layer (15-20cm) and the bottom layer (30-35cm) are selected for comparative analysis. The undisturbed soil sample is collected and its dry bulk density is determined by the drying method. The mechanical composition of the soil is determined by the pipette method.

(2) Determination of soil double-ring infiltration process
During the test, the inner ring and the outer ring are respectively inserted 10cm under the ground and a constant water head of 5.5cm is maintained, so as to compare the soil infiltration process under the constant water head. Three undisturbed soil samples are collected before the test and used to calculate the dry bulk density and water content of the soil.

(3) Soil single-ring infiltration test
First install a single ring, find a relatively flat place, slowly press the PVC single ring vertically into the soil, note to use a level meter to control the level of the single ring. After the single ring is installed in place, take a soil sample from near the ring to measure the initial water content of the soil and take another soil sample to measure the soil bulk density, and collect the corresponding soil sample for analyzing the soil mechanical composition. At the beginning of the test, use a small bottle to take water and quickly inject water into the single ring. At the same time, start the stopwatch. when the water surface in the single ring disappears, immediately add another small bottle of water and record the time; repeat this step until duration of the three (or more than three times) consecutive injections is equivalent, it is considered to reach a stable state. At this moment, stop the test, and take water from the single ring to measure the saturated water content.

3. Test results and analysis

3.1. Change of basic physical properties of soil in spoil disposal site
(1) Soil bulk density
Soil bulk density is an important parameter indicating the soil physical properties. The soil bulk density determines the total soil porosity, infiltration rate and soil separation rate, and it is therefore, the soil erosion rate can be indirectly reflected by measuring the soil bulk density. In order to understand the changes of soil infiltration rules at different levels in the highway spoil disposal site and the differences from the original landforms through exploring the changes in bulk density of soil in the soil profile at the highway spoil disposal site, this study selects loose earthwork and construction roads in the spoil disposal site as representatives of typical underlying conditions during the construction of spoil disposal site; and selects the woodland, grassland, and arable land to represent underlying conditions that are not disturbed by construction. Figure 3-1 shows the change in soil bulk density at different levels under various conditions of the underlying surface. For loose earthwork and compacted pavement, the bulk density of the top soil is the largest, and the bulk density of the middle soil is the lowest. For other underlying surface conditions, the soil bulk density of the basement soil is the largest and the soil bulk density of the top soil is the smallest. From the perspective of changes in bulk density of soils at the same level and different land use types, the top soil bulk density decreases in sequence of road surface, loose earthwork, farmland, grassland, and woodland. The middle soil bulk density is the largest on the pavement and the smallest on the woodland. The bulk density of the basement soil is the smallest in loose earthwork and the soil bulk density of the pavement is the largest. The changes in bulk density of the basement soil is relatively small under various conditions of the underlying surface.
Figure 3-1 Changes in soil bulk density at different levels under different land use types

(2) Composition of soil machineries

In this study, the pipette method is used to analyze the particle size composition of the soil at the top, middle and bottom layers under the above conditions, and fitting is then conducted. For the top, middle and basement soils, the trends of relative changes in the soil particle size composition under different underlying surface conditions are relatively consistent, and all show the relationship of fine particle content decreasing in the order of woodland, loose earthwork, grassland, farmland and pavement. For woodland, the ground is covered with a deep layer of litters, so fine particles that are more prone to erosion are protected. However, for the construction road at the spoil disposal site, the soil has large bulk density, small soil porosity, the saturated hydraulic conductivity and soil infiltration rate are both small, so even small rainfalls can cause a large slope runoff, and further lead to high erosion of fine particles on the construction road. This can explain why the fine particle content is the lowest.

3.2. Changes of soil infiltration process in spoil disposal site

In order to better understand the differences between the slope runoff, infiltration and erosion processes of highway spoil disposal site and the situations under other underlying surface conditions, the study conducts a double-ring infiltration test on loose earthwork at highway spoil disposal site, construction road at highway spoil disposal site, woodland, and farmland.
Figure 3-2 Comparison of infiltration process of soil surface layer under different underlying surface conditions

The soil surface infiltration process under different underlying surface conditions is shown in Figure 3-2. The initial infiltration rate and stable infiltration rate of the woodland are significantly higher than those under other underlying surface conditions, followed by loose earthwork, and the infiltration filtration of the farmland is slightly larger than that of the road. The soil infiltration rate of woodland is about 6.5 times that of loose earthwork at highway spoil disposal site, and 45 times that of farmland and road. This is due to the effect of the root system, the soil in the woodland is relatively loose and porous, and the soil infiltration rate is large. Correspondingly, the critical rainfall intensity and capacity that result in runoff are both greater than that under other underlying surface conditions, that is, due to the impact of human activities, changes in soil erosion and runoff will be caused inevitably.

Table 3-1 Soil infiltration rate under different underlying surface conditions

| Underlying surface conditions | Loose earthwork | Woodland | Farmland | Road surface |
|------------------------------|-----------------|----------|----------|--------------|
| Steady infiltration rate (mm/min) | 1.4             | 9        | 0.2      | 0.18         |

3.3. Change of soil water-holding curve at spoil disposal site

Soil water-holding curve is the basis for estimating the parameters of soil water movement and further simulating the unsaturated soil water movement. The study uses this method to derive the soil water-holding curves of different levels under different underlying surface conditions, to compare the differences in unsaturated soil water movement parameters between the highway spoil disposal site and the undisturbed underlying surface.

4. Conclusion

The soil physical properties of the spoil disposal site and its adjacent underlying surface conditions are quantitatively analyzed, the double-ring and single-ring soil infiltration tests are conducted to compare and analyze the differences in soil hydrological characteristics of loose earthwork of the highway spoil disposal site, the construction road at highway spoil disposal site and the adjacent undisturbed underlying surface conditions, the results showed that the soil infiltration rate of the loose earthwork in the highway spoil disposal site is significantly lower than that of the woodland but higher than that of the farmland. The soil infiltration rate of the construction road at highway spoil disposal site is the lowest; due to the small soil infiltration rate and good network connection structure, the construction road at
spoil disposal site will be bound to become one of the most important runoff catchment point in the highway spoil disposal site, and its runoff drainage may cause severe soil erosion.

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