Study on response characteristics of red clay slope under evaporation rainfall condition

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Abstract: Evaporation rainfall is one of the main causes of slope failure. Red clay belongs to special soil, and the failure mode of the slope is different from that of the general soil slope. In this paper, based on the theory of similarity simulation, a test model of red clay slope similar to the prototype is established in a certain proportion. Sensors are embedded in different positions of the slope to carry out the change rule of physical and mechanical indexes of the red clay slope under the condition of evaporation and rainfall. The results show that the water content of the slope increases during the rainfall period, the surface water content of the slope is obviously affected by the rainfall intensity, and the water content of the slope decreases in the drying period. Under the action of evaporation and rainfall, the internal temperature of slope is stable, and the surface temperature changes significantly. The pore water pressure of the top, shoulder and slope changes little with the times of evaporation and rainfall, and the pore water pressure at the foot of slope is obviously affected by evaporation and rainfall. Evaporation rainfall causes obvious horizontal displacement of red clay slope. The earth pressure increases in the rainfall period and decreases in the static and dry periods. With the increase of evaporation rainfall times, the earth pressure increases gradually.

1. Introduction
Guizhou belongs to southwest China, located in Yunnan Guizhou Plateau, with warm and humid climate, belonging to subtropical humid monsoon climate. Generally, the average temperature of the coldest month (January) is 3°C ~ 6°C, and the average temperature of the hottest month (July) is 22°C ~ 25°C, with more precipitation, obvious rainy season, more overcast days and less sunshine. The problem of red clay slope is becoming more and more serious because of evaporation rainfall [1]. The main research on the process of evaporation rainfall of slope are as follows. LV Haibo et al. [2] selected Nanning undisturbed expansive soil for evaporation rainfall test, and revealed the relationship between the shear strength of soil and the number of cycles, cycle amplitude and water content. Xu Dan et al. [3] selected the remolded unsaturated expansive soil as the research object, focusing on the analysis of the influence of water content, positive pressure and cycle times on the shear strength of expansive soil. Chen Yongai et al. [4] selected the expansive soil as the experimental sample and carried out 1-12 evaporation rainfall tests. The relationship between the shear strength, expansion rate, expansion force and evaporation rainfall path and cycle times was discussed. Zhou Jian et al. [5] conducted evaporation rainfall test by stacking expansive soil slope model. After each evaporation rainfall, the soil samples were cut at different positions of the slope and the direct shear test was carried out. The above research shows that evaporation rainfall is one of the main causes of slope failure. The current research mainly focuses on expansive soil slope. Red clay belongs to special soil, which has the characteristics of high moisture content, high plasticity and high void ratio. The research on response characteristics of red
clay slope under evaporation rainfall condition is less \((\text{[6]} \text{[7]} \text{[8]})\). In this paper, based on the theory of similarity simulation, a test model of red clay slope similar to the prototype is established according to a certain proportion. Sensors are embedded in different positions of the slope, and the change rules of physical and mechanical indexes such as water content, temperature, pore water pressure, displacement, etc. of the red clay slope under the condition of evaporation and rainfall are analyzed.

2. **Slope Model**

The soil samples used in this experiment are from the West Campus of Guizhou University. The basic characteristics of soil material are brownish red, relatively wet, uniform soil, and dense structure \((\text{[9]})\). The slope model size is 300cm * 150cm * 140cm, and the slope rate is 1:1.5. The optimal moisture content of soil is 22.98\%, and the dry density is controlled to be 1.65 g / cm\(^3\) in the process of slope stacking. Sensors are embedded in different positions of the slope, including 14 sets of temperature sensors, 14 sets of pore water pressure sensors, 14 sets of water content sensors, 18 sets of displacement sensors and 16 sets of earth pressure sensors. The temperature, pore water pressure, water content and earth pressure sensors are buried on the left side of the slope, the horizontal displacement sensors are buried on the center line of the slope, and the vertical displacement sensors are buried on the right side of the slope, in which the water content, pore water pressure, temperature and earth pressure gauges are successively separated by 100mm. As shown in Figure 1 and Figure 2.

![Figure 1](image1.png)

**Figure 1** buried profile of water content, temperature, pore water pressure and earth pressure sensors

![Figure 2](image2.png)

**Figure 2** buried section of displacement sensor

3. **Evaporation Rainfall Test Plan**

3.1. **Rainfall Device**

The rainfall system of this experiment is qyjy-501 (502) portable rainfall simulator. The equipment is mainly composed of water supply system, rainfall system and control system. The rainfall intensity is 60mm / h.
3.2. Drying Device
The drying system adopts six bath bars evenly arranged on the top, middle and bottom of the slope model, each of which is 1180W. At the foot of the slope, an electric fan is used to increase the air flow to accelerate the drying of the slope.

3.3. Test Plan
This evaporation rainfall simulation of such a climate process: rainy day → cloudy day → sunny day, i.e. rainfall for one hour (rainy day), rainfall of 60mm, then standing for 24 hours (cloudy day), finally heating and drying with Yuba and blowing with electric fan for 40 hours (sunny day). According to this procedure, the evaporation rainfall was completed 5 times.

4. Result Analysis

![Figure 3 The relationship between water content and time in different depths of slop top](image)

![Figure 4 The relationship between water content and time in different depths of slope toe (40cm)](image)

It can be seen from Fig. 3 and Fig. 4 that the surface water content of the slope is obviously affected by rainfall intensity, and the larger the increase of water content is. With the increase of evaporation rainfall times, the increase of water content is more obvious. In the early stage of drying, the internal temperature of the slope has not increased, the internal water has not evaporated but continues to infiltrate, and the water content continues to increase. With the increase of evaporation rainfall times, the water content of slope soil increases.
It can be seen from Fig. 5 that the change amplitude of slope temperature increases with the increase of evaporation rainfall times. The temperature change in the slope is relatively stable. After the second cycle, the difference of temperature change amplitude is gradually obvious. The temperature change outside the slope is obvious and much larger than that inside the slope.

It can be seen from Fig. 6 and Fig. 7 that the variation range of pore water pressure at the top, shoulder and slope surface with the number of evaporation rainfall is not large, but the pore water pressure at the foot of slope is obviously affected by evaporation rainfall and fluctuates within -5kpa-3kpa. On the whole, the pore water pressure at the toe of slope is much higher than that at other parts. The increase of pore water pressure results in the decrease of effective stress and the decrease of shear strength of slope.
It can be seen from Fig. 8 and Fig. 9 that evaporation rainfall causes obvious deformation of red clay slope. The overall deformation is mainly composed of horizontal displacement caused by rainwater infiltration, which is less affected by evaporation, and basically increases in the whole evaporation rainfall process.
Figure 11 relationship curve between earth pressure and time at different positions with burial depth of 10 cm

The earth pressure increases in the rainfall period and decreases in the static and dry periods. With the increase of evaporation rainfall times, the earth pressure increases gradually. The first two cycles have great influence on soil pressure of slope. The soil pressure reaches the maximum at the top of the slope, followed by the foot of the slope, and the minimum at the slope.

5. Conclusion
(1) The surface water content of slope is obviously affected by rainfall intensity, and the larger the increase of water content is, the more obvious the increase of water content is with the increase of evaporation rainfall times. The water content in drying period has the phenomenon of decreasing lag. With the increase of evaporation rainfall times, the water content of slope soil increases.

(2) The variation of slope temperature increases with the increase of evaporation rainfall times. The temperature change in the slope is relatively stable. After the second cycle, the difference of temperature change amplitude is gradually obvious. The temperature change outside the slope is obvious and much larger than that inside the slope.

(3) The pore water pressure of the top, shoulder and slope changes little with the times of evaporation and rainfall, and the pore water pressure at the foot of slope is obviously affected by evaporation and rainfall.

(4) Evaporation rainfall causes obvious horizontal displacement of the red clay slope, which is less affected by evaporation. In the whole process of evaporation rainfall, the slope basically increases. The change of slope has an impact on the increase of horizontal displacement.

(5) The earth pressure increases in the rainfall period and decreases in the static and dry periods. With the increase of evaporation rainfall times, the earth pressure increases gradually. The first two cycles have great influence on soil pressure of slope. The soil pressure reaches the maximum at the top of the slope, followed by the foot of the slope, and the minimum at the slope.

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