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Study on slope stability under continuous heavy rainfall

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Abstract: Slope is one of the major geological disasters which affects the safety of human life and property. And rainfall is an important factor to induce slope damage. Based on the theory of saturation - non - saturation and slope stability, Geo - studio software was used to simulate the change of pore water pressure and safety coefficient at the exit of Tuanshan tunnel in Wuhan East Lake Tunnel under the action of continuous heavy rain at 3d300mm. And the stability of the slope is obtained. The results show that the infiltration of rainfall leads to the decrease of the pore water pressure, that is, the decrease of the suction of the substrate, the elevation of the groundwater level, and the decrease of the shear strength of the slope, resulting in the decrease of the slope safety factor. Damage, it is necessary to take protective measures and reinforcement.

Keywords: Continuous rainfall; slope; saturated-unsaturated theory; stability study; numerical simulation

1. Introduction

In recent years, the slope stability evaluation has gradually become one of the basic problems of geotechnical engineering research, especially after the occurrence of natural disasters such as slope instability, it has been widely concerned, the slope stability Analysis has become an important research direction in geotechnical engineering [1-3]. The instability of the slope not only poses a great threat to the people's well-being, but also increases the cost of construction units and the input of the state. However, rainfall is an important factor causing the slope failure [4]. Therefore, Slope of the destruction of the project is very necessary. In view of this, this paper uses Geo-studio to simulate the rainfall infiltration law and stability analysis of slope under rainfall, and provide the scientific basis for later treatment and protection.

2. Project overview

2.1 Slope profile

The slope is located at the exit of Tuanshan Tunnel of Wuhan East Lake Tunnel Project. The excavation of the tunnel leads to the formation of slope. The elevation of the highest point of the left boundary of the slope is 39.5m, the elevation of the highest point of the right boundary Is 30.75m, the slope width is 20.4m, the slope is generally steep. The specific situation shown in Figure 1.

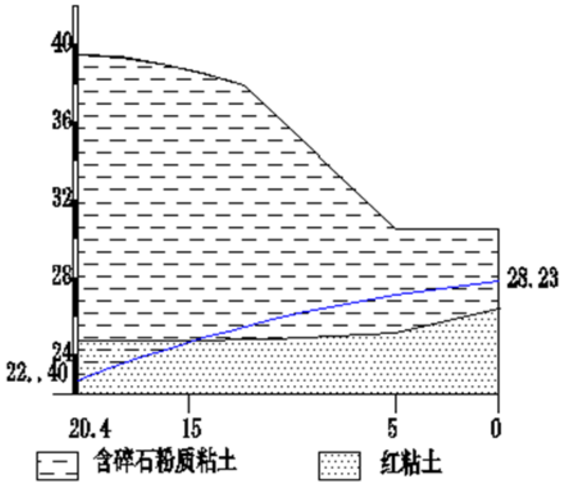

Figure 1. Geological profile

2.2 Engineering geological conditions

The slope mainly consists of two layers of soil, the upper layer is composed of crushed stone silty clay, the lower red clay. The maximum buried depth of the upper soil is 14m, mainly distributed in the posterior wall of the slope, the front distribution is less, the lower soil depth is deeper, the thickness is smaller, the thickness is about 3m. As the upper layer is crushed stone with silty clay, so its relatively large porosity of the infiltration of rainwater, rainfall conditions for the destruction of the slope buried under the hidden danger, the blue line shown in the figure is the distribution of groundwater level.

2.3 Meteorological and hydrological data

Wuhan is a subtropical continental monsoon climate, with four distinct seasons, mild climate, abundant rainfall characteristics of the climate. The average temperature is 28.8 ℃ ~ 31.4 ℃, the extreme maximum temperature is 41.3 ℃ (1934.8.10). The lowest temperature is in January, the average is 2.6 ℃ ~ 4.6 ℃, and the extreme minimum temperature is -18.1 ℃. ° C (November 30, 1977). 7, 8 and 9 months for the high temperature period, from December to February the following year for the low temperature period, and frost and snow occurred.

The region has abundant rainfall and humid climate. The annual average rainfall is 1261.2mm. The rainfall is concentrated in June to August, accounting for 41% of the annual rainfall. The maximum annual rainfall of 2107.1mm, the maximum daily rainfall of 317.4mm (1959.6.9), the average evaporation of the vessel is 1447.9mm, the absolute humidity of 16.4 mbar, the humidity coefficient of 0.90, the atmospheric impact of a sharp depth of 1.35m.

3. Numerical model

3.1 Numerical calculation model

According to the actual situation of the slope, in Geo-studio in the establishment of the model shown in Figure 2, the model a total of 1158 nodes, 1110 cells.

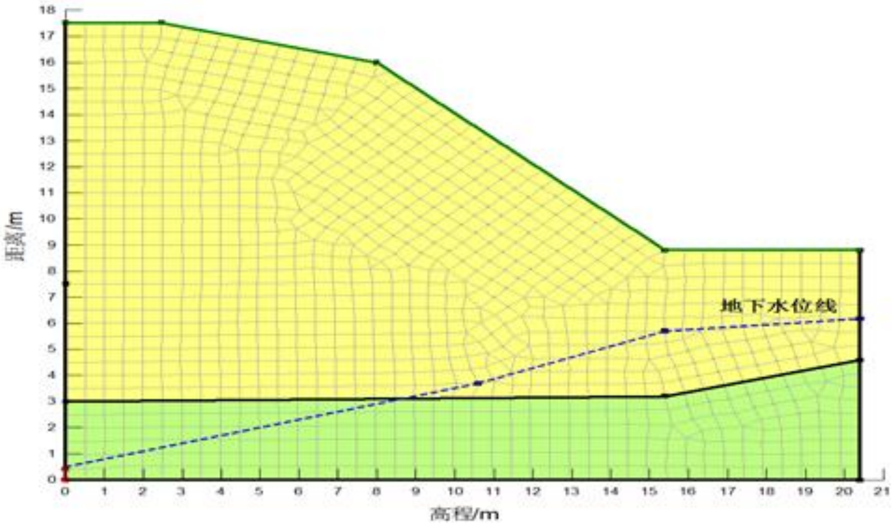

Figure 2. Slope model

3.2 Boundary conditions

In order to represent the groundwater level in the slope, the groundwater level line of the model adopts multi-point segmentation method. The total head of the left boundary is 0.4m, the total internal head of the slope is 5.6m, Of the total head is 6.2m The specific situation shown in Figure 2 dotted line shown below.

Because both soils are non-saturated, both soils are set to a saturated-unsaturated state. The left and right borders above the water level are set to free-flowing faces. The surface of the landslide is set to show the real rainfall condition with the flow boundary conditions changing with rainfall infiltration.

3.3 Rainfall and rainfall time

By the rainfall conditions in Wuhan can be obtained, the maximum short-term rainfall of 300mm or more, in order to truly reflect the stability of the slope, to take a total of 300mm rainfall of 3d rain.

4. Analysis of rainfall infiltration

As can be seen from the geological section, there are two layers of soil and have unsaturated areas, through the indoor test can be measured in two layers of soil saturated permeability and saturated water content as shown in Table 1, soil water characteristics The trace calls the seep module that comes with it.

Table 1. Soil saturated permeability coefficient and saturated moisture content

Soil	Saturated permeability coefficient (K_s)	Saturated water content (θ_s)
Silty clay containing gravel	0.127m/d	0.4
Red clay	0.00532m/d	0.3

4.1 Pore water pressure change

During the 3-day rainfall, the pore water pressure in the soil is obtained as shown in Figure 3.

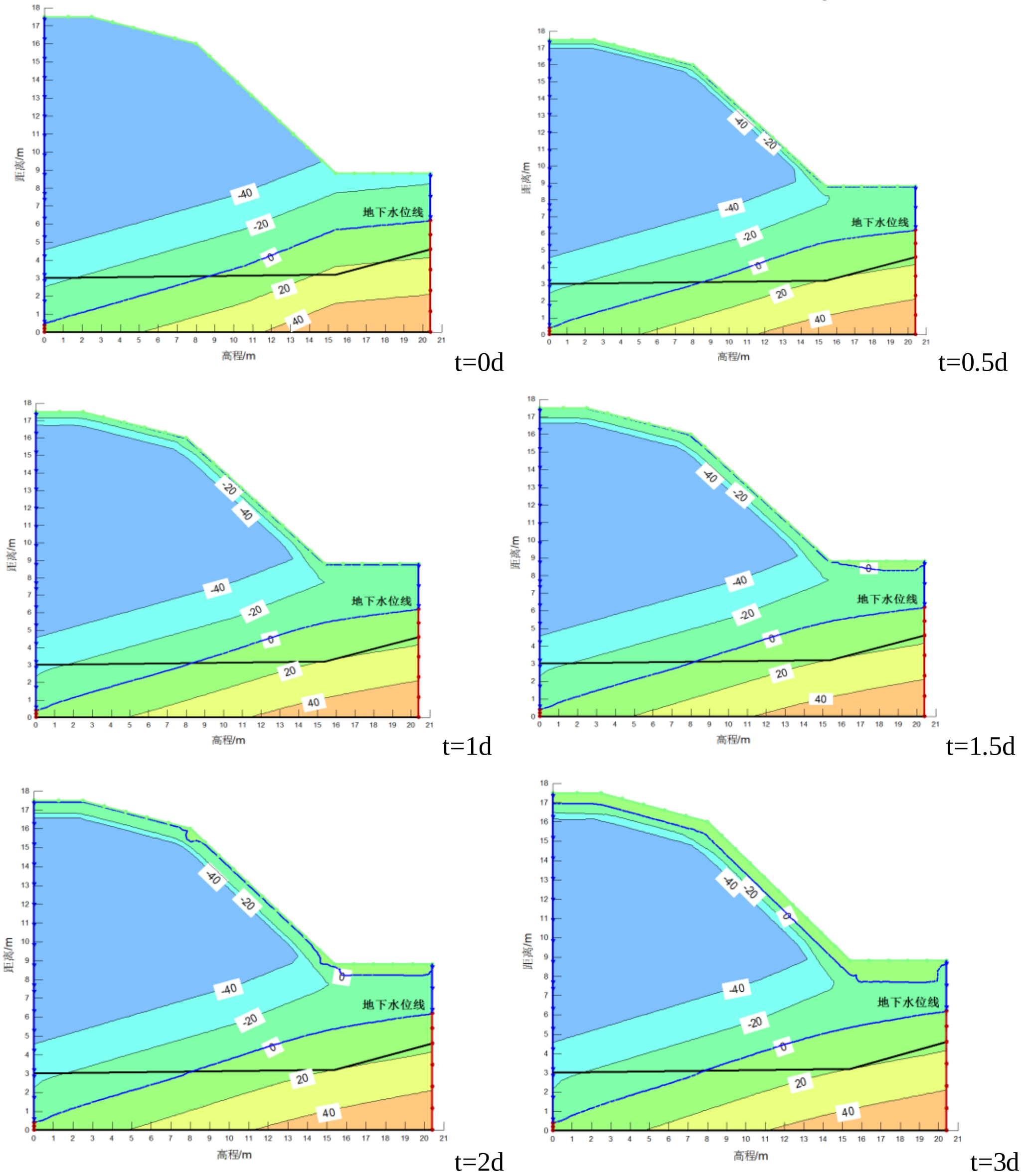

Figure 3. Slope in 0 d, 0.5 d, 1 d, 1.5 d and 2 d, 3 d pore water pressure distribution

From Figure 3, it can be seen that the pore water pressure of the down-slope descended after 3d rain, and there was a certain amount of water on the surface of the slope body. In the 0-1d slope, the wetting line of the slope body is faster and the pore water pressure of the slope body also changes greatly. The saturation area is formed on the surface of the 1d-3d slope body and the area of the saturated zone over time Especially in the slope angle where more water, slope of the pore water pressure change rate slowed down.

The reason for this is that the soil is relatively dry in the early period of rainfall and the rainfall can infiltrate rapidly, so the pore water pressure of the soil is very obvious. However, the infiltration rate of the upper soil is relatively small, The saturated area is generated on the surface of the slope, and the saturated area will move to the slope angle of the slope under the action of gravity. Therefore, in order to prevent the accumulation of water in the slope of the increase in soil gravity increase the slope of the sliding force, in the governance must be set to drain the slope of the surface of the surface water discharged in time.

4.2 Variation of groundwater level

In order to accurately reflect the changes of the groundwater level, the change of the pore water pressure, which is the most obvious change of the groundwater level, is selected to reflect the uplift of the groundwater level from the data as shown in Figure 4.

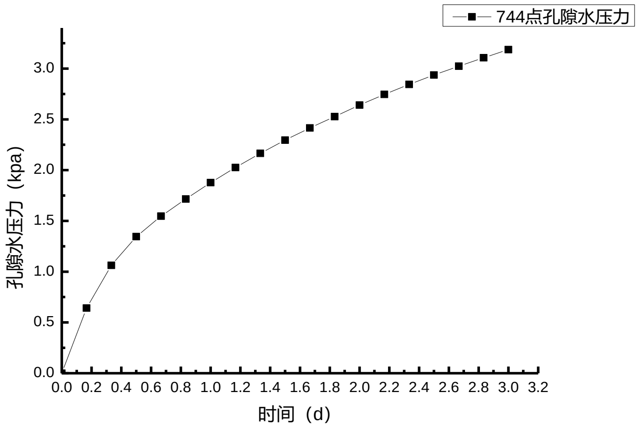

Figure 4. 744 points of pore water pressure time curve

It can be deduced from the figure that the pore water pressure changed from 3.2 kp to 0.317 m at the point 744 after 3 days of rainfall, and the uplift of the groundwater level is obvious, which also affects the negative pore water pressure inside the slope That is, the change of matrix suction.

5. Slope stability analysis

5.1 Stability analysis theory

When the slope is in the saturated-unsaturated state, there is a negative pore water pressure above the groundwater level, that is, the matrix suction. The rainfall will change the groundwater level and the matrix suction, thus affecting the slope shear strength. Fredlund [4] proposed the Mohr-Coulomb criterion based on the saturated-unsaturated state, and given the shear stress and the shear strength of the shear stress and shear strength of the landslide, which has great influence on the shear strength of the soil and the safety factor of the landslide of the expression formula:

$$\tau_f = c' + (\sigma_n - u_a)\tan\varphi' + (u_a - u_w)\tan\varphi^b$$

$$\tau = \frac{\sigma_y - \sigma_x}{2}\sin 2\alpha + \tau_{xy}\cos 2\alpha$$

$$\sigma_n = \frac{\sigma_y + \sigma_x}{2} + \frac{\sigma_x - \sigma_y}{2}\cos 2\alpha - \tau_{xy}\sin 2\alpha$$

According to the principle of equilibrium, from the above can be the safety factor of the landslide formula:

$$F_S = \frac{\int_T \tau_f d\Gamma}{\int_T \tau d\Gamma} \tag{2}$$

When calculating with the slitting method, the safety factor of the landslide can be calculated by considering the force balance:

$$F_s = \frac{\sum\left(c'\beta\cos\alpha + \left(N - u_w\beta\frac{\tan\varphi^b}{\tan\varphi'} - u_a\beta\left(1 - \frac{\tan\varphi^b}{\tan\varphi'}\right)\right)\tan\varphi'\cos\alpha\right)}{\sum N\sin\alpha + \sum kW - \sum D\cos\omega \pm \sum A} \tag{3}$$

where β: The length of the bar base. α: The angle between the tangent of the bottom edge of the bar and the horizontal direction. N: Normal to the bottom of the bar. kW: Horizontal vibration loads on striped hearts. D: Line load. ω: The angle between the line load and the horizontal direction. A: Externally applied water pressure

5.2 Stability analysis of landslide

In this paper, the seep of Geo-studio is used to calculate the slope safety factor of the slope by introducing the pore water pressure value into the slope. Through the indoor test can be obtained by the physical and mechanical parameters of soil [5] as shown in Table 2:

Table 2. Slope stability analysis and shear strength parameters

Soil	Severe KN/m2	Cohesion C/KPa	Friction angle φ
Silt containing clay, clay	21	4	27
Red clay	17.8	35	1

The stability factors of the slope stability are shown in Table 3 below:

Table 3. Stability safety coefficient under different calculation method

Calculation method	M-P method	Jan B U	Bishop	Ordinary
Before rain	1.096	1.026	1.102	1.035
After the rain	0.893	0.821	0.924	0.843

From the table of the safety factor can be obtained, regardless of the kind of calculation method of slope stability coefficient has a reduction to about 0.2, and from a stable state into an unstable state, it must take measures to ensure the slope of the slope stability.

6. Conclusions and suggestions

Based on the basic survey report of the slope, through the method of numerical simulation, it is found that under the effect of continuous heavy rainfall, the slope of the tunnel is likely to be lost Stable, and the following conclusions:

1）The pore water pressure of the slope will change under continuous heavy rainfall, but with the increase of time, the infiltration rate of the soil will be slowed down, which will lead to the change of the slope. The saturated area in the slope increases the soil 's gravity, which is not conducive to the stability of the slope.

2） Continuous heavy rainfall will also lead to the uplift of the groundwater level line, which will reduce the negative pore water pressure, that is, the decrease of the shear force of the slope, which will decrease the slope stability.

3）In order to ensure the stability of the slope, it is suggested that the drainage surface of the slope should be arranged to drain the surface water in time, so as to avoid the impact of the rainfall on the slope in the area where the rainfall is relatively abundant. The formation of saturated areas in the slope to increase the weight of the soil, and can also play an anchor in the slope to increase its shear strength and concrete in the slope surface to prevent the infiltration of rainwater to affect the slope stability.

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