Numerical simulation of slope stability of the abandoned dreg site

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Abstract. A mathematical model of No. 1 abandoned dreg site of the newly-built highway from Xiangle village, Pingyao County to Hougou village, Qinyuan County was developed using GeoStudio software. The stability of the abandoned dreg site was simulated and analyzed under rainstorm. As a result, the influence of rainfall infiltration on slope seepage field is not limited to the rainfall process. The slope stability coefficient decreases significantly during the rainfall and the decreases slightly after the rainfall stopped due to continuous rainwater seepage. The minimum safety coefficient is 2.292 at 24h, greater than the allowable value, which demonstrates that the slope is stable.

1 Introduction

During highway construction, plenty of abandoned dregs would be produced in subgrade and tunnel engineering. The large-scale abandoned dreg site thus was formed with the continuous accumulation of dregs. The irregular loose slope formed by natural stacking of abandoned dregs can easily cause serious soil and water loss under adverse conditions such as rainfall or earthquake, and even cause geological disasters such as landslide and debris flow, seriously threatening the surrounding environment and the safety of residents and their property. This problem has attracted the attention of scholars at home and abroad, and a series of studies have been performed on the stability of abandoned dreg site^[1-2], and the obtained research results have also been widely applied in practice. At present, two common methods are often applied for the stability analysis: one finite element strength reduction method(SRM)^[3-4], another limit equilibrium method(LEM)^[5-7].

The seepage field of No. 1 abandoned dreg site of the newly-built highway from Xiangle village, Pingyao County to Hougou village, Qinyuan County was studied using unsaturated seepage theory. Based on the seepage calculation results, the limit equilibrium method was used to simulate the slope stability, which provides theoretical basis for the safety assessment of the abandoned dreg site.

2 The project

2.1 Geographic and geomorphic conditions

The project began in Jinzhong basin, west of Pingyao county, ends in the hinterland of TaiYue mountains, at

the border of Pingyao county and Qinyuan county. The route is of dramatic topographic fluctuation along the start-end with significant differences in morphology. The terrain is generally low in the northwest and high in the south and east, with obvious ladder-shaped characteristics. The lowest altitude is 737 m, located at the starting point of the route and the highest point is near Shennan Tunnel at the watershed between Pingyao and Qinyuan, with an altitude of 1607.9m. The maximum relative altitude difference is up to 870.9m.

2.2 Climate

The project is located in the warm temperate continental monsoon climate zone, with an average annual temperature of 10.4°C, an extreme maximum temperature of 39.6°C, an extreme minimum temperature of -24.1°C, and a frost-free period of 160 days. The average annual rainfall is 415.5mm, and most of the precipitation is concentrated in July, August and September, accounting for more than 75% of the total annual precipitation. The average annual evaporation capacity is 1932.9mm. The depth of frozen soil is 55~80cm.

3 The slope model

3.1 Calculation section

The abandoned dreg site is located in Pingyao County, Shanxi Province, with an area of about 4.11 hm². The designed dreg height is 1030~1050m and the designed drag capacity is about 420000m³. Figure 1 depicts the abandoned dreg site plan and section, in the same

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direction with the slope and perpendicular to the topographic contours.

Figure 1. The abandoned dreg site plan and section

3.2 Boundary conditions and calculation parameters

The boundary conditions of the model are:

(1) The surface of the slope is the infiltration boundary, which is set as the flow boundary. The infiltration rate varies with the infiltration capacity of rock and soil, when the rainfall intensity is less than the surface infiltration capacity of rock and soil mass, the

infiltration rate is equal to the rainfall intensity. At this time, flow boundary condition is set:

$$k_n \frac{\partial \theta}{\partial n} \bigg|_{\Gamma_2} = -v(x, y, z, t) \quad (1)$$

Otherwise, when the rainfall intensity is greater than the surface infiltration capacity of rock and soil mass, the water will be lost along the slope, and the infiltration rate will be the infiltration capacity of rock and soil body itself. In this case, the boundary condition is the head boundary:

$$\theta_{\Gamma_1} = \theta_1(x, y, z, t) \quad (2)$$

(2) The boundary conditions on both sides of the model are related to the groundwater level. The head boundary is set below the groundwater level and zero flow boundary is set above the groundwater level. The bottom is assumed to be impervious boundary.

The rainstorm intensity is 0.018m/h, with the rainstorm return period of 30a and the duration of 6h. The total simulation time is 24h. The physical and mechanical parameters of rock and soil mass are shown in Table 1.

Table 1. Physical and mechanical parameters of rock and soil mass.

Rock and soil mass type	Density ρ (kN•m ⁻³)	Internal friction angle φ (°)	Cohesion C (kPa)	Coefficient of permeability (ms ⁻¹)
Abandoned dreg	1.51	45.3	0	6.5×10^{-5}

4 The simulation results

4.1 Seepage analysis

Figure 2 depicts the seepage fields of the slope at different times. As can be seen from the figure, the rain

infiltrate into the dregs continuously. Fig.2(c)~(e) indicate that the infiltration is still even after the rain stopped. As a result, the water content of the dregs increases, the matric suction decreases, and the total water head rises.

Figure 2. The seepage field

4.2 Stability analysis

Morgenstern-Price method allowing for arbitrary shape sliding surface was applied for the slope stability simulation. Figure 3 depicts the slope deformation at different times. As can be seen from the figure, the safety

coefficient reduces significantly from the initial 2.793 to the end of the rainfall 2.301. After the rainfall stopped, the stability coefficient decreases slightly due to continuous rainwater seepage. The minimum safety coefficient is 2.292 at 24h, greater than the allowable value, which demonstrates that the slope is stable.

Figure 3. The slope deformation

5 Conclusion

- (1) The influence of rainfall infiltration on slope seepage field is not limited to the rainfall process. Seepage still exists after the end of rainfall. Therefore, it is far from enough to perform the slope stability analysis only during the rainfall.
- (2) The slope stability coefficient decreases significantly during the rainfall and the decreases slightly after the rainfall stopped due to continuous rainwater seepage.
- (3) The minimum safety coefficient is 2.292 at 24h, greater than the allowable value, which demonstrates that the slope is stable.

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