Study on the influence of water level change on the stability of the back surface of soil slope

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Abstract: The change of the water level in the reservoir area has an important influence on the stability of the slope on both sides. In order to study the influence, from the numerical experiments, based on a typical loess slope model, using GeoStudio software to simulate a hydrological cycle. Results: the reservoir has obvious influence on the stability of slope on both sides of the back surface of the water, in the storage process of the reservoir, landslide stability coefficient reducing rate showed "low-high-low" landslide in the reservoir area, waterfront back flood, increased stability, higher rate of performance as "slow-fast-slow".

1. Introduction

The process of land consolidation in the gully region of the Loess Plateau, in order to solve the problem of urban life and agricultural irrigation water and soil conservation, built a large reservoir and dam. Although the dam construction in a certain period of time so that local farmers improve the agricultural ecological environment has been improved; however, dam long-term operation, making a serious impact on the stability of loess slope in Northern Shaanxi area from around the reservoir induced loess landslide is developed, a serious threat to the safety of life and property of local residents.

The change of reservoir water storage and water level changes the hydrogeological conditions of the slope in the reservoir area and adjacent area, and has a significant influence on the stability of the adjacent slope. Reservoir and dam construction of the underground water level Yong high, and then induced landslide collapse and other geological disasters. A certain theoretical study has been carried out on the influence of the change of water level on the stability of the slope\cite{1,2}. Combined with a project, GUO Zhihua\cite{3} has numerically simulated the influence of water level descending speed, reservoir water level descending time and permeability coefficient on slope stability. Based on the strength reduction finite element method, Liu Jinlong\cite{4} analyses the influence of the rise and descending speed of the water level on the stability of the slope. It is found that the water level should be kept slowly to keep the slope in a relatively safe state, whether it is drainage or water storage. Li Yan\cite{5} is based on the slope quantitative analysis, and the traditional limit equilibrium analysis method is used to determine the stability coefficient of the slope under six different working conditions, and its stability is analyzed and evaluated. Study on the influence of reservoir water level under complex conditions, a lot of research has been carried out, and some progress has been made\cite{6,7}.

From the numerical experiments of the loess slope stability problems, research the influence of the slope stability of reservoir water level changes. With a typical slope as an example, analysis results based on the sliding surface stress state, using the finite element method of stress analysis of different
time step stability coefficient of slope, to explore the mechanism of landslide caused by water level changes, so as to provide theoretical basis for related engineering management.

2. Analysis model and calculation parameter
In order to study the influence of the reservoir water level change on the stability of the back surface slope, a typical landslide model is established. The physical and mechanical parameters of the landslide calculation are taken as table 1. According to the stratum structure on the main section of the landslide, the finite element model of Figure 1 is set up to carry on the simulation analysis. The boundary model changes with time in the initial water level consistent with bedrock elevation; highest water level is 1018m, the reservoir water level is higher than that of 30m at the bottom of the bedrock for the landslide slope, as impervious boundary, the right foot is the constant head boundary. The model is 400m long and 119m high, which is divided into 885 grid units.

| geotechnical category       | elasticity modulus (kPa) | poisson ratio | effective internal friction angle (°) | effective cohesive force (kPa) | severe (kN/m²) | permeability coefficient (cm/s) |
|-----------------------------|--------------------------|---------------|--------------------------------------|------------------------------|---------------|---------------------------------|
| loess slider                | 50000                    | 0.35          | 19.3                                 | 20                           | 18.0          | 5 × 10⁻⁴                        |
| loess slippery bed          | 80000                    | 0.30          | 18.0                                 | 50                           | 19.0          | 3 × 10⁻⁴                        |
| bedrock slippery bed        | 1500000                  | 0.26          | —                                    | —                            | 24            | —                               |

The change of reservoir water level is shown in Figure 2. The speed of 1.5m/d rises by 20 days, 30m and 1018m water level for 60 days. After that, the water level of reservoir has started to decline from 2.5m/d to 988m and run for 78 days. Based on unsaturated seepage theory, numerical simulation is applied to simulate transient seepage field and groundwater level change in adjacent area during a hydrological cycle, and then analyze the effect of transient seepage on the stability of old landslide on the back shore.

3. Analysis of failure mechanism of landslide

3.1 The reservoir water level rise
Analysis of pore water pressure on the sliding surface curves of Figure 3, the reservoir landslide before drying, the pore water pressure were negative in soil; the reservoir began to store water, the reservoir water to the surrounding underground water infiltration, adjacent area gradually increased, the pore water pressure on the sliding surface to positive value. With the gradual increase of reservoir water level, more sliding surfaces are soaked by water, while the positive pore water pressure section
expands, while the upper part of the slide surface is not affected by reservoir water, and the pore water pressure line coincides.

In the back edge of the landslide, the middle section of the slide surface, the position of the front edge is selected respectively, to analyze the shear stress and the shear strength of the reservoir during the rise of the water level, as shown in Figure 4. Before the reservoir is impounded, the shear strength of each position of the sliding surface is greater than the shear stress value, and the landslide is stable. With the reservoir, the underground water level in adjacent areas increased, the shear strength gradually reduced, the middle of the landslide slip surface, shear stress with normal stress increase in the increase of landslide, when the reservoir water level rise 30m, front shear stress value exceeds the strength value, soil stress yield. The strength and shear stress of the middle section of the sliding surface are close after 80 days of storage. If the reservoir water level is increased again, the middle soil will also yield.

The reservoir, the underground water level rise in adjacent areas, have a "floating" effect on the dorsal waterfront landslide soil on the soil surface gradually saturated, pore water pressure changed from negative to positive, effective shear strength decreases with the increase of pore water pressure, the slope stability coefficient decreases from 1.12 to 1. It is shown in Figure 5 that the reduction rate of the landslide stability coefficient is "low - high - low" during the reservoir storage process. The initial impoundment period, the reservoir water level rose rapidly, but due to the space distance and the permeability of soil, underground water level rise in adjacent areas there is a certain lag; with the reservoir water to the surrounding water line has high permeability, smooth, the landslide stability coefficient decrease rate increasing; as time continues, due to the reservoir water level the underground water level limit, adjacent area rise rate becomes slow after a certain period of time, the rate of decrease of stability coefficient to reduce landslide. According to the simulation results, it can be concluded that if the water level of the reservoir continues to rise, the landslide will be completely unstable.
3.2 The reservoir water level falls down

Analysis of pore water pressure on the sliding surface curves of Figure 6, the reservoir flood before the underground water saturated soil, the pore water pressure in the pore water pressure in the soil above the ground water level is negative; the reservoir began to flood, the underground water level in adjacent areas decreased, and increased unsaturated surface. After 80 days, the water level was reduced to 988m, and the soil of the slide surface was all in the unsaturated state.

The shear stress and shear strength of the sliding surface in the back edge of the landslide, the middle section of the slide surface and the front edge of the sliding surface are selected respectively. The shear stress and the shear strength of different rainfall holding are shown in Figure 7. Before the flood discharge, the shear strength of each position of the sliding surface is greater than the shear stress value, and the stability of the landslide is poor. Along with the reservoir flood discharge, the groundwater level in the adjacent area descends, and the shear strength of the leading edge and the middle section of the slide increases gradually. The shear stress of the leading edge of the landslide decreases slightly with the normal stress, and the shear stress of the middle and the trailing edge is basically unchanged. When the reservoir water drained all in 12 days, the groundwater level in the adjacent area lagged behind, so the leading edge strength in 80 days increased slowly and remained unchanged after 80 days.

![Fig.6 Pore water pressure of sliding surface changes with time](image)

![Fig.7 Change of stress and strength at different positions of sliding surface with time](image)

Based on the above analysis shows: the drawdown rate (within 12 days by 30m), due to spatial distance and soil permeability limit, makes the back landslide drawdown waterfront lag; in early flood, landslide stability (stable slow growth coefficient increased by 0.01 in 12 days), when after the completion of the reservoir flood, underground water level slope in falling. At this time, the drop rate of water level increases and the growth rate of stability increases as the drop of groundwater in the landslide and the adjacent area increases. When the groundwater level falls below the sliding surface, the drop of water level is no longer sensitive to the stability of the landslide. It can be seen that the stability of the landslide in the reservoir area continues to increase and the increase rate is "slow fast slow", as shown in Figure 8.

![Fig.8 The change of landslide stability factor with time](image)
4. Conclusion
The change of reservoir water level is an important factor affecting the stability of slope. In this paper, the stability of back surface of soil slope under the change of reservoir water level is simulated and analyzed by numerical experiment. The following results are obtained.

(1) The change of reservoir water storage and water level has a significant influence on the stability of the adjacent slope.

(2) In the process of reservoir storage, the reduction rate of landslide stability coefficient is "low high low".

(3) The stability of the back water shore landslide during reservoir flood discharge is increasing continuously, and the rate of increase is "slow fast slow".

Acknowledgements
The study is supported by Shaanxi land engineering construction group Internal research projects (DJNY2017-24).

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