Study on hydrodynamic characteristics and deformation failure of large-scale accumulation landslide

Dissertation Submitted to

HoHai University

In Fulfillment of the Requirements

For the Degree of

Doctor of Engineering Science

by

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December 2020 Nanjing, China

Abstract

Accumulation landslides with soil-rock mixture structure are widely distributed in the reservoir area of hydropower engineering in southwest China. Combined with the case of Dahua accumulation landslide in the Huangdeng – Dahuaqiao reservior areas in Lancang river basin, the material composition and structural characteristics of the accumulation were studied, refined structural modelling procedure of the accumulation was developed, the unsaturated-saturated characteristics and water-induced degradation characteristics of the accumulation material were also studied via experiment. The study tried to reveal the evolution and failure mechanism of accumulation landslide under hydrodynamic conditions. The results and main conclusions are as follows:

(1) The probability density function of the equivalent diameter, long axis, medium axis and short axis of the rock block were statistically analyzed. The *barycenter connection method* was proposed to determine the relative planar position of rock blocks, then the modelling procedure and program of 2D refined structure model were developed. The rock block model library of Dahua accumulation was preliminarily established, based on the CNOA algorithm to determine the relative spatial position of rock blocks, the 3D refined structure model of Dahua accumulation was constructed.

(2) The pressure plate test on the soil-water characteristics (SWCC) of slip soil in Dahua accumulation was carried out. It revealed that the unsaturated seepage characteristics of Dahua conforms to the van Genuchten model. Furthermore, the saturated seepage test was also conducted. It indicated that the saturated seepage characteristics follows one of the Non-Darcy's law flow which is called Forchheimer model, i.e., $J = av + bv^2$. The result showed that seepage in the accumulation is controlled both by the linear flow and nonlinear flow. When the confining pressure increases to a certain value, the seepage is dominated by the quadratic term of velocity in the equation.

(3) Through the unsaturated triaxial test of the slip soil in Dahua accumulation, it is

pointed out that most samples under low confining pressure were fail *around the rock*; on the contrary, the *rock block breakdown* failure may occur under high confining pressure. When the rock block proportion is low, the failure mode is similar to that of soil. With the increase of rock block proportion, failure mode of the sample is gradually changed into multi-shear zone composite failure. Further study also suggested that the apparent cohesion of shear strength decreases with the increase of water content, the overall process is similar to that of matric suction in SWCC, the relation between apparent cohesion and water content was given.

(4) The water movement model in the accumulation was derived and the seepage process was also simulated numerically. It revealed that the seepage characteristics were similar to the laminar flow when the rock block proportion is relatively low. With the increase of rock block proportion, the seepage tends to *flow around rock blocks*, its seepage characteristics show the feature of turbulence flow. Based on the aforementioned achievements, the program of Non-Darcy's Forchheimer-VG model was developed. The results showed that there is a strong consistency in the pore water pressure distribution between the final state of the Darcy and Non-Darcy flow. But the seepage process was quite different from each other.

(5) Achievements on the characteristics of seepage and water-induced shear strength degradation under hydrodynamic conditions of the accumulation were applied to the Dahua landslide case. The calculation of underground water was proved little difference with field monitoring data. The result shows that the safety factor variation of Dahua landslide is mainly caused by the rising and drawdown of reservoir water level. The fluctuation of reservoir water leads to the strength degradation and destruction of rock-soil mass in front of the landslide. The shear outlet of potential slip surface is located below the reservoir water level, so it is particularly necessary to pay close attention to the underwater and riverfront areas of the landslide.

Keywords: Accumulation landslide; hydrodynamic characteristic; deformation failure; non-Darcy seepage; water-induced degradation; Dahua landslide