Fracturing and Buckling Mechanisms of Submerged High-Steep Unstable Rock Masses: A Case Study of Longmenzhai Unstable Rock Mass in the Three Gorges Reservoir Area (Postprint)

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Abstract

Since 2008, the water level in the Three Gorges Reservoir area has cyclically fluctuated between 145–175 m annually. This water level drawdown has induced significant deterioration and damage effects in the rock mass within the 30 m-high water-level-fluctuation zone, resulting in the formation of 18 water-involved high-steep dangerous rock masses that threaten the safety of the Yangtze River waterway within the Chongqing reservoir area of the Three Gorges Project. To reveal the fracturing and buckling failure mechanism of water-involved high-steep dangerous rock masses, this study takes the Longmenzhai dangerous rock mass in the Three Gorges Reservoir area as a typical case study. Employing research methods including field geological survey, in-situ data monitoring, and rock mechanics testing, we investigated the deterioration and damage patterns of rock mass within the water-level-fluctuation zone and the crack and fissure propagation process, obtaining the following research conclusions and insights: (1) Refined window surveys revealed that the linear density of both transverse and longitudinal joints and fissures in the rock mass within the water-level-fluctuation zone is greater than that in the rock mass above the zone, while in-situ acoustic wave CT testing revealed that the development degree of fissures and fracture zones in the rock mass within the water-level-fluctuation zone is greater than that in the rock mass below the zone; (2) The complex hydrodynamic conditions brought about by reservoir water level drawdown include wet-dry cycling, hydraulic coupling, water flow migration, and water flow impact, with the deterioration and damage mechanisms of rock mass manifested in three aspects: chemical mechanism, mechanical mechanism, and physical mechanism; (3) The fracturing and buckling failure mechanism of water-involved high-steep dangerous rock masses is manifested as follows: under complex hydrodynamic

conditions, the rock mass within the water-level-fluctuation zone undergoes deterioration and damage effects, leading to the propagation and generation of cracks and fissures in the base area, causing the overlying rock mass to gradually separate from the parent rock mass, ultimately resulting in a dynamic disaster process for water-involved high-steep dangerous rock masses and inducing secondary surge disasters. This study applied refined window surveys and in-situ acoustic wave CT testing, while independently developing and manufacturing a rock mechanics strength testing device that provides hydraulic coupling and seepage conditions, effectively revealing the deterioration and damage patterns and mechanisms of rock mass within the water-level-fluctuation zone, and providing new research ideas for revealing the instability mechanisms of similar types of high-steep dangerous rock masses.

Full Text

Study on the Crush-Failure Mechanism of High and Steep Dangerous Submerged Rocks: A Case Study of the Longmen Dangerous Rock in the Three Gorges Reservoir Area, China

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Abstract

Since 2008, the water level in the Three Gorges Reservoir has fluctuated annually between 145–175 m, causing significant deterioration and damage to rock masses within the 30 m drawdown zone. This has resulted in the formation of 18 high and steep dangerous rock masses that threaten navigation safety in the Chongqing section of the reservoir. To investigate the crush-failure mechanism of such water-affected high-steep dangerous rocks, this study examines the Longmen Dangerous Rock as a typical case using field geological surveys, in-situ monitoring, and rock mechanics testing. The research focuses on deterioration patterns and crack propagation processes in the drawdown zone, leading to the following conclusions: (1) Detailed window mapping reveals that both horizon-

tal and vertical joint fracture line densities in the drawdown zone exceed those in the rock mass above it, while in-situ acoustic CT testing demonstrates that fracture and fracture zone development is more extensive in the drawdown zone than in the rock mass below; (2) The complex hydrodynamic conditions associated with water level fluctuations include wet-dry cycling, hydraulic coupling, water flow migration, and flow impact, with rock mass deterioration mechanisms manifesting through chemical, mechanical, and physical processes; (3) The crush-failure mechanism of water-affected high-steep dangerous rocks proceeds as follows: under complex hydrodynamic conditions, rock mass in the drawdown zone undergoes deterioration damage, leading to crack propagation and new fracture formation at the base, which gradually separates the overlying rock mass from the parent body, ultimately triggering a dynamic failure process and inducing secondary surge disasters. This study employs detailed window mapping and in-situ acoustic CT testing, and independently developed a rock mechanics strength testing apparatus capable of providing hydraulic coupling and seepage conditions, effectively revealing deterioration patterns and mechanisms of rock mass in the drawdown zone. The research provides new insights for understanding the instability mechanisms of similar high and steep dangerous rocks.

Keywords: Three Gorges Reservoir; Longmen Dangerous Rock; rock mass deterioration law; rock mass deterioration mechanism; dynamic disaster

Note: Figure translations are in progress. See original paper for figures.