Postprint of Seismic Stability Analysis of a Tailings Dam

Authors: Meng Wang

Date: 2025-08-04T18:11:20+00:00

Abstract

Tailings storage facilities are major hazard sources for metal and non-metal mines, and red mud is a strongly alkaline tailings discharged during alumina extraction. In recent years, the number of tailings storage facilities has been continuously increasing, and earthquakes are also important factors causing tailings dam failures. Currently, domestic and foreign experts and scholars have made significant progress in environmental impact assessment and treatment technologies for red mud, but research on the dynamic characteristics of red mud is relatively limited. Therefore, further investigation into the dynamic characteristics of red mud tailings holds important theoretical value for the safe and stable operation and seismic design of tailings storage facilities. This study takes red mud as the research object, utilizes GCTS cyclic triaxial apparatus to investigate the variation patterns of dynamic parameters of red mud under different consolidation confining pressures and consolidation ratios, and combines Geo-Studio software to conduct stability analysis of tailings storage facilities. The main research contents are as follows:

Through dynamic deformation tests, it was obtained that under different confining pressures and consolidation ratios, the dynamic stress-strain backbone curve of red mud exhibits a nonlinear increase with increasing dynamic strain; the dynamic elastic modulus and dynamic shear modulus decrease at different rates with increasing dynamic strain, while increasing with increasing consolidation confining pressure and consolidation ratio; the damping ratio increases with increasing dynamic strain, while decreasing with increasing consolidation confining pressure and consolidation ratio.

Through dynamic strength tests on red mud tailings, the dynamic strength curves and dynamic strength parameters under different consolidation confining pressures and consolidation ratios were investigated. The results indicate that the greater the consolidation confining pressure and consolidation ratio applied to the specimen, the more cyclic loading cycles are required to reach failure; the

dynamic internal friction angle and dynamic cohesion decrease nonlinearly with increasing number of vibration cycles, and can be fitted using a power function.

Combining the above experimental results, Geo-studio software was utilized to conduct an in-depth study on the stability of tailings dams under seismic action. The research shows that under seismic action, the horizontal displacement of the tailings dam increases with increasing dam height, with the maximum peak horizontal displacement occurring at the dam crest; liquefaction occurs in the shallow upstream region of the tailings dam, and post-earthquake liquefaction has minimal impact on the safe operation of this tailings dam; the minimum safety factor calculated using the Bishop method for the dam slope meets code requirements.

Full Text

Preamble

Seismic Stability Analysis of a Tailings Dam

Wang Meng
North China University of Water Resources and Electric Power, Zhengzhou 450045

Abstract

Tailings dams represent major hazards for metal and non-metal mining operations. Red mud, a strongly alkaline tailings material produced during alumina extraction, poses particular concerns. As the number of tailings dams continues to grow, earthquake-induced failure has emerged as a critical risk factor. While significant progress has been made in environmental impact assessment and remediation technologies for red mud, research on its dynamic characteristics remains limited. Consequently, further investigation into the dynamic properties of red mud tailings is of important theoretical value for the safe operation and seismic design of tailings storage facilities.

This study characterizes red mud using GCTS dynamic triaxial testing to investigate variations in dynamic parameters under different confining pressures and consolidation ratios, complemented by numerical stability analysis using Geo-Studio software. Dynamic deformation tests reveal that the dynamic stress-strain backbone curves exhibit nonlinear growth with increasing strain amplitude. Both dynamic elastic modulus and dynamic shear modulus decrease at varying rates as strain increases, while increasing with higher confining pressure and consolidation ratio. Conversely, the damping ratio increases with strain but decreases with greater confining pressure and consolidation ratio.

Dynamic strength tests on red mud tailings examine strength curves and indices under various confining pressures and consolidation ratios. Results demonstrate that higher applied confining pressure and consolidation ratio require a greater number of cyclic loading cycles to induce failure. Dynamic friction angle and

dynamic cohesion decrease nonlinearly with increasing vibration cycles, a relationship that can be effectively fitted using power functions.

Integrating these experimental findings, Geo-Studio software was employed to investigate the seismic stability of the tailings dam. The analysis indicates that horizontal displacement increases with dam height under seismic loading, reaching its maximum at the dam crest. Liquefaction occurs in the shallow upstream zone of the tailings dam, though post-earthquake liquefaction has minimal impact on safe operation. The minimum safety factor calculated using Bishop's method satisfies regulatory requirements.

Keywords: red mud; tailings dam; dynamic triaxial test; dynamic characteristics; dynamic stability analysis

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