Postprint: Dynamic Stability and Spectral Characteristics of Toppling Rock Masses under Seismic Action

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Abstract

To more reasonably evaluate the dynamic stability of rock masses under seismic action, a mass-viscoelastic model was employed to simulate the two main controlling surfaces of toppling-type unstable rocks. Based on the principles of structural dynamics, a dynamic response analysis model and equations of motion for toppling-type rock masses were established, and a calculation method for the dynamic stability coefficient of toppling-type rock masses was developed using the Newmark-β method. This method was applied to the WY2 rock mass developed in a steep cliff zone at Luoyi Village, Leshan City, Sichuan Province, yielding a dynamic stability coefficient of 1.198, which represents a 10.6% increase compared with the results calculated by the traditional pseudo-static method. Subsequently, acceleration response signals of the rock mass in different directions were analyzed based on wavelet packet transform. The results indicated that the wavelet packet energy ratios of the low-frequency component (0.1-18.76 Hz) all exceeded 50%, and the sum of energy ratios E1, E2, and E3 for frequency bands 1 to 3 in the n1 and s2 directions was greater than 95%, demonstrating that seismic damage first occurred in the n1 and s2 directions of the WY2 rock mass under bidirectional seismic action, causing the rock mass to fail primarily along these two directions. Finally, seismic waves with different PGAs were applied to the rock mass, and the variation characteristics of marginal spectra of acceleration response signals in different directions were analyzed based on HHT. The results showed that the marginal spectrum amplitude in the n1 direction > that in the s2 direction > that in the s1 direction that in the n2 direction, with the seismic energy in the n1 and s2 directions being most pronounced under seismic loading. Rock mass failure consistently initiated with seismic damage along these two directions, revealing that the failure mode of this rock mass is outward toppling failure, which is consistent with the wavelet packet analysis results. When the PGA exceeded 0.2g, the marginal spectrum

peaks of acceleration signals in the n1 and s2 directions increased rapidly, at which point the rock mass experienced complete instability failure.

Full Text

Study on dynamic stability and spectral characteristics of toppling perilous rock under earthquake

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Abstract

To more reasonably evaluate the dynamic stability of perilous rock masses under seismic action, this study employs a mass-viscoelastic model to simulate the two primary control surfaces of toppling perilous rock. Based on principles of structural dynamics, a dynamic response analysis model and equations of motion are established, and a computational method for the dynamic stability coefficient is developed using the Newmark-β method.

The proposed method is applied to the WY2 perilous rock mass located in a steep cliff zone of Luoyi Village, Leshan City, Sichuan Province, yielding a dynamic stability coefficient of 1.198. This result represents a 10.6% increase compared with calculations using the traditional pseudo-static method.

Wavelet packet transform is subsequently employed to analyze acceleration response signals in different directions. The findings demonstrate that the wavelet packet energy proportion in the low-frequency range (0.1–18.76 Hz) exceeds 50% in all cases, and the sum of energy proportions E1, E2, and E3 for frequency bands 1 through 3 in both the n1 and s2 directions surpasses 95%. This indicates that seismic damage initiates first in the n1 and s2 directions of the WY2 perilous rock mass under bidirectional seismic action, causing failure to develop primarily along these two orientations.

Finally, seismic waves with different peak ground accelerations (PGAs) are applied to the perilous rock mass, and the marginal spectrum variations of acceleration response signals in different directions are analyzed using the Hilbert-Huang Transform (HHT). The results reveal that marginal spectrum amplitudes follow the relationship: n1 direction $>$ s2 direction $>$ s1 direction   n2 direction. The seismic energy is most pronounced in the n1 and s2 directions, with damage consistently initiating along these orientations, which reveals an outward toppling failure mode that aligns with the wavelet packet analysis results. When the PGA exceeds 0.2g, the marginal spectrum peaks of acceleration signals in the n1 and s2 directions increase rapidly, indicating complete instability of the perilous rock mass.

Keywords: toppling perilous rock; dynamic stability; Newmark-β method; wavelet packet transform; Hilbert-Huang transform; failure

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