Seismic Response and Kinematic Process of the Shiguchuan Landslide: Insights from Geological Investigation and Numerical Simulation (Post-print)

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Abstract

Tianshui City is located in the transition zone between the West Qinling Mountains and the Loess Plateau, a region significantly affected by strong earthquakes. Historical seismic events have triggered numerous landslides in this area. Through a comprehensive approach combining field investigation, drilling, and numerical simulation, the seismic response and failure mechanism of loess-bedrock slopes have been revealed, and the movement process of the Shiguchuan landslide has been examined under both basic and rare earthquake conditions. The main findings are as follows: The seismic response of loess-bedrock slopes is primarily controlled by the thickness of the loess layer, topographic features, and soil properties. The loess-bedrock interface exhibits significant elevation amplification, surface amplification, and loess layer amplification effects. Below the mid-slope elevation, horizontal acceleration amplification factors (AAFs) dominate the vertical component, while above the mid-slope elevation, this relationship is reversed. Spectral analysis shows that seismic amplification of loess-bedrock slopes exhibits obvious frequency-dependent characteristics. Significant amplification of the horizontal component (2.2-2.5 Hz) and vertical component (5-6 Hz) was observed in the upper-middle slope section. The failure mechanism of the Shiguchuan landslide is characterized by high-position shear sliding of loess along the bedrock interface at medium-high slope gradients. Under rare earthquake conditions, the movement and deposition behavior of the landslide determined through numerical simulation generally align with the post-failure characteristics observed through field investigation, indicating that the Shiguchuan landslide may have been triggered by strong ground motion with peak ground acceleration (PGA) $ $0.6g. These results are of great significance for understanding the dynamic behavior of such landslides and the potential triggering seismic intensity.

Full Text

Preamble

Seismic response and run-out process of the Shiguchuan landslide: Insights from geological investigations and numerical simulation

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Abstract

Tianshui City is located in the transition zone between the West Qinling Mountains and the Loess Plateau, a region significantly affected by strong earthquakes that have historically triggered numerous landslides. Through an integrated approach combining field investigations, drilling, and numerical simulation, this study reveals the seismic response and failure mechanism of loess-bedrock slopes and examines the run-out process of the Shiguchuan landslide under both basic and rare seismic conditions.

The seismic response of loess-bedrock slopes is primarily controlled by loess layer thickness, topographic features, and soil properties. The loess-bedrock interface exhibits significant elevation, surface, and loess layer amplification effects. Below mid-slope elevations, horizontal acceleration amplification factors (AAFs) dominate the vertical component, while this relationship reverses above mid-slope elevations. Spectral analysis reveals distinct frequency-dependent characteristics of seismic amplification in loess-bedrock slopes, with notable amplification of the horizontal component (2.2–2.5 Hz) and vertical component (5–6 Hz) in the upper-middle slope section. The Shiguchuan landslide' s failure mechanism is characterized by high-position shear sliding of loess along the bedrock interface on steep slopes. Under rare seismic conditions, numerical simulations of the landslide' s movement and deposition behavior align well with post-failure features observed in field investigations, suggesting the Shiguchuan landslide was likely triggered by strong ground motion with peak ground acceleration (PGA) $\geq$ 0.6g. These results are significant for understanding the dynamic behavior of such landslides and the potential seismic intensity required for triggering.

Keywords: Loess-bedrock landslide; Seismic response; Failure mechanism; Run-out process

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