Multi-stage Failure Mechanism and Risk Assessment of Colluvial Landslides under Earthquake-Rainfall Temporal Sequences: Case Study Postprint

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Abstract

Strong earthquake action can induce co-seismic slope instability, while the temporal superposition effect of post-seismic rainfall further aggravates damage to colluvial landslide masses. Research on the instability mechanism and risk assessment of colluvial landslides under combined earthquake-rainfall actions is of great significance for disaster prevention and control in earthquake-affected regions. This study investigates the K3-H05 landslide on the Hailuogou Scenic Area road under the influence of the 2022 Luding earthquake. First, a generalized model before and after the landslide was established based on post-earthquake UAV imagery data, and the dynamic damage to the slope caused by the earthquake was analyzed using a combination of limit equilibrium method and Newmark method. Second, the stability of the slope under post-earthquake rainfall was evaluated based on stress-seepage coupling analysis combined with regional rainfall data. Finally, the secondary instability process of the landslide was simulated using the finite volume method with the (I) rheological constitutive model. The results demonstrate that seismic acceleration is sharply amplified at the slope crest and at the interface between loose colluvium and bedrock, with the permanent displacement of the slope corresponding to a very high risk level, consistent with instability characteristics from field investigations. Due to the loosening of the rock-soil structure after the earthquake, the safety factor of the slope drops below 1 under continuous rainfall, indicating an extremely high risk of secondary landslides. The instability motion destroyed the existing scenic area road and formed a deposit at the slope toe. Post-disaster reconstruction measures including elevated bridges and graded drainage systems are recommended. This study provides technical support for slope risk prevention and control in strong earthquake zones.

Full Text

Preamble

Multi-stage Instability Mechanisms and Risk Assessment of Accumulation Landslides under Sequential Earthquake-Rainfall Actions: A Case Study

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Abstract: Strong earthquakes can trigger co-seismic slope instability, and the sequential superposition effect of post-earthquake rainfall further exacerbates damage to accumulation landslide masses. Research on the instability mechanisms and risk assessment of accumulation landslides under combined earthquake-rainfall actions is therefore crucial for disaster prevention and control in seismic regions.

This study investigates the K3-H05 landslide along the Hailuogou scenic area road, which was impacted by the 2022 Luding earthquake. First, a generalized model of the pre- and post-landslide conditions was established based on post-earthquake UAV imagery data, and the dynamic damage to the slope caused by the earthquake was analyzed using a combination of limit equilibrium methods and the Newmark method. Second, the stability of the slope under post-earthquake rainfall conditions was evaluated through stress-seepage coupling analysis combined with regional rainfall data. Finally, the secondary failure process of the landslide was simulated using a finite volume method incorporating the (I) rheological constitutive model.

The results demonstrate that seismic acceleration was sharply amplified at the slope crest and at the interface between the loose accumulation layer and bedrock, with permanent slope displacement corresponding to an extremely high risk level, consistent with instability characteristics observed in field investigations. Due to post-earthquake loosening of the rock-soil structure, the slope safety factor dropped below 1 under continuous rainfall, indicating an extremely high risk of secondary landsliding. The failure motion destroyed the existing scenic area road and formed a deposit at the slope toe. Post-disaster reconstruction measures including elevated bridges and a graded interception-drainage system are recommended. This study provides technical support for slope risk prevention and control in strong earthquake zones.

Keywords: slope stability; strong earthquake; post-earthquake rainfall; finite volume method; limit equilibrium method

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