Postprint: Development and Evolution Characteristics and Disaster-Forming Process of Geological Hazards on Mountainous Arterial Highways under the Lushan Earthquake

Authors: Wu Kai, Xuebin Yi, Fu Xiaodong, Du Wenjie, Ding Haifeng, Zhao Haisong, practice field

Date: 2025-09-02T14:54:22+00:00

Abstract

Investigating the development and evolution characteristics and disaster-forming dynamic processes of typical geological hazards along trunk highways in strong earthquake-prone mountainous areas holds significant theoretical and practical importance for early hazard identification, risk assessment, and disaster prevention and mitigation of transportation corridors. This paper takes the southern segment of the Longmenshan fault zone as the study area, integrates field investigation, remote sensing interpretation, and GIS spatial analysis techniques, and reveals the superimposed influence patterns of multi-phase earthquakes in Lushan in 2013 and 2022 on co-seismic geological hazards along the Baoxing section of National Highway 351; further employs the three-dimensional two-phase Material Point Method (MPM) to quantitatively simulate the entire process of initiation-motion-river blockage of the Xinhua Village high-level accumulation landslide, and discusses key techniques for scenario deduction of high-level collapse-slide disasters in earthquake-frequent zones. The results indicate that: (1) A total of 215 co-seismic geological hazards developed in the study area in 2022, mainly distributed within the 1500 m elevation range on both banks of the Donghe River valley, on slopes of 30°–50°, with a common distribution characteristic with the 2013 co-seismic geological hazards being that high-steep slopes of hard rock are high-incidence areas for disasters. (2) The development and distribution of the 2022 co-seismic geological hazards are primarily controlled by geomorphological, river, and fault factors, with weak spatial coupling with the epicenter location; hazard points with significant impact on the highway mainly develop at prominent mountain parts with multiple free faces and near fault zones, and are significantly influenced by superimposed multi-phase earthquakes and historical

rainfall. (3) The Xinhua Village high-level landslide, under the superimposed influence of multi-phase earthquakes, rainfall, freeze-thaw cycles, and other factors, exhibited progressively upward-expanding retrogressive deformation over the past decade, and finally experienced large-scale overall instability and blocked the river channel under the 2022 strong earthquake action; the three-dimensional two-phase MPM simulation reproduced the entire process of landslide motion → water entry surge → dam formation by accumulation, with results showing the landslide volume is approximately 760,000 m^3, the maximum travel distance is approximately 609 m, and the surge height reaches up to 8 m; the simulated post-motion accumulation morphology basically matches the actual field conditions. The research findings provide theoretical and technical support for pre-disaster risk assessment and post-disaster reconstruction of trunk highways in strong earthquake-prone mountainous areas.

Full Text

Development, Evolution Characteristics, and Kinematic Processes of Geological Hazards Along Mountain Arterial Highways Under the Lushan Earthquake

Wu Kai[1], **Yi Xuebin**[1], **Fu Xiaodong**[2,3]*, **Du Wenjie**[2,3], **Ding Haifeng**[2,3], **Zhao Haisong**[1], **Xi Tian**[2,3]

[1]Sichuan Highway Planning, Survey, Design and Research Institute Ltd., Chengdu, Sichuan 610041, China

Abstract

Investigating the development, evolution, and kinematic processes of typical geological hazards along arterial highways in strong earthquake-prone mountainous regions holds significant theoretical and practical importance for early hazard identification, risk assessment, and disaster mitigation in transportation corridors. This study focuses on the southern segment of the Longmenshan fault zone, integrating field investigation, remote sensing interpretation, and GIS spatial analysis to reveal the superimposed influence patterns of multi-phase Lushan earthquakes in 2013 and 2022 on co-seismic geological hazards along the Baoxing section of National Highway 351. Furthermore, using three-dimensional two-phase Material Point Method (MPM), we quantitatively simulated the complete process of initiation, movement, and river-blocking of the high-level accumulation landslide in Xinhua Village, and discussed key techniques for scenario forecasting of high-level collapse and landslide hazards in earthquake-prone areas.

Results indicate that: (1) A total of 215 co-seismic geological disasters occurred in 2022 within the study area, predominantly distributed on slopes of 30°–50° within the 1500 m elevation range along both banks of the Donghe River valley.

A shared distribution characteristic with the 2013 co-seismic geological disasters is that high-steep slopes composed of hard rock represent high-incidence areas. (2) The development and distribution of the 2022 co-seismic geological disasters were primarily controlled by geomorphology, river systems, and fault factors, showing weak spatial coupling with the epicenter location. Hazard points with significant highway impact mainly developed at prominent mountain locations with multiple free faces and near fault zones, significantly influenced by superimposed multi-phase earthquakes and historical rainfall. (3) The high-level landslide in Xinhua Village, affected by superimposed multi-phase earthquakes, rainfall, and freeze-thaw action, exhibited progressive retrogressive deformation with continuous upward expansion over the past decade, finally resulting in large-scale instability and river blockage under the 2022 strong earthquake. Three-dimensional two-phase MPM simulation reproduced the complete process of landslide movement, water entry, wave generation, and dam formation. Results show the landslide volume was approximately 760,000 cubic meters, with a maximum movement distance of about 609 m and a maximum wave height of 8 m. The simulated post-movement accumulation morphology basically matches actual field conditions. These findings provide theoretical and technical support for pre-disaster risk assessment and post-disaster reconstruction of arterial highways in strong earthquake-prone mountainous areas.

Keywords: Lushan earthquake; geological disasters; development and evolution characteristics; three-dimensional two-phase MPM; kinematic process analysis

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