Development Patterns of Road Geological Hazards and Post-Disaster Reconstruction Strategies in the Hailuogou Scenic Area at the Epicenter of the Luding Earthquake: Postprint

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Abstract

The "9.5" Luding earthquake induced extensive coseismic geological hazards in the Hailuogou scenic area at the epicenter, with 50% of the scenic area roads located within the earthquake intensity IX (9-degree) affected zone, resulting in severe road damage and complete loss of traffic capacity. To investigate the development patterns of geological hazards and post-disaster reconstruction strategies for roads in the Hailuogou scenic area, this study comprehensively employed multi-dimensional and three-dimensional methods including remote sensing, LiDAR, UAV oblique photogrammetry, ground surveys, geological investigations, and automatic structural plane identification to conduct systematic research on geological hazards in the study area from regional to site-specific scales. The results indicate: (1) A total of 503 coseismic geological hazard sites developed in the study area, covering a total area of $3.75\$\times10^{6}m\^{}\{2\}\$$, primarily distributed on the right side of road sections K10–K15, within the elevation range of 1900 m–2900 m, and on slopes of 30°–60°. (2) The distribution patterns of geological hazards are mainly controlled by topographic, lithological, epicentral, and fluvial factors, showing weak spatial coupling with the main fault. (3) The instability modes of geological hazards can be classified into three types: high-position collapses, accumulation body landslides, and shallow slope surface failures, characterized by large quantities, linear distribution, and varying scales. High-position collapses mainly occurred in hard rock areas such as granite and dolomite, while landslides and shallow failures primarily took place in soft rock regions including schist and slate, as well as on the banks of the Moxi Terrace glaciofluvial deposits. (4) The deep-incised canyon topography and high peak ground acceleration generated seismic amplification effects in hard rock slope break zones, resulting in massive high-position collapses; under strong

earthquake action, the overall instability of thick accumulation body landslides exhibited a time-lag phenomenon. (5) Based on the development and evolution patterns of geological hazards, the post-disaster reconstruction project for roads in the Hailuogou scenic area adopted the concept of "hazard-mitigation route selection," adhering to the principle of "avoiding major hazards while treating minor ones." This involved using four tunnels to bypass high-position collapses, thirteen bridges to cross potential debris flow gullies, and combining in-situ treatment measures for earthquake-damaged slopes such as grouted steel pipe piles and anchor bolt frame beams to enhance the disaster prevention and resistance capacity of scenic area roads. The research findings systematically reveal the development patterns of geological hazards in the Luding earthquake epicentral region, and the proposed post-disaster reconstruction strategies have been comprehensively applied in engineering practice, providing important support for hazard identification, assessment, and road post-disaster reconstruction work in strong earthquake zones.

Full Text

Preamble

Development Patterns of Geological Disasters and Post-Disaster Reconstruction Strategies for Roads in the Hailuogou Scenic Area at the Epicenter of the Luding Earthquake

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Abstract

The "9.5" Luding earthquake triggered extensive co-seismic geological disasters in the Hailuogou scenic area at the epicenter. Approximately 50% of the road network was located within the intensity IX (9-degree) seismic influence zone, resulting in severe damage and complete loss of traffic capacity. To investigate the development patterns of these geological disasters and formulate effective post-disaster reconstruction strategies for the Hailuogou scenic area roads, this study employed a multi-dimensional, integrated approach combining remote sensing, LiDAR, UAV oblique photogrammetry, ground surveys, geological exploration, and automatic structural plane recognition techniques to conduct systematic research on geological disasters from regional to site-specific scales.

The results indicate: (1) A total of 503 co-seismic geological disasters developed in the study area, covering a cumulative area of 3.75$×$10^6 m^2. These were primarily distributed on the right side of the road section between K10~K15, within the elevation range of 1900 m~2900 m and on slopes of 30°~60°. (2) The distribution patterns of geological disasters are predominantly controlled

by topographic, lithological, epicentral, and riverine factors, showing weak spatial coupling with the main fault. (3) Failure modes can be classified into three categories: high-position collapse, accumulation landslide, and shallow slope collapse, characterized by large quantities, linear distribution, and varying scales. High-position collapses mainly occurred in hard rock areas such as granite and dolomite, while landslides and shallow collapses were primarily observed in soft rock regions comprising schist and slate, as well as on the banks of the Moxi terrace glacial deposits. (4) The deep-incised canyon terrain and high peak ground acceleration (PGA) generated seismic amplification effects at hard rock slope breaks, resulting in massive high-position collapses. Under strong seismic action, thick accumulation landslides exhibited delayed overall failure phenomena. (5) Based on the development and evolution patterns of geological disasters, the post-disaster reconstruction of the Hailuogou scenic area roads adopted the concept of "disaster-reduction routing," adhering to the principle of "avoiding large-scale disasters while treating small-scale ones." Specifically, four tunnels were constructed to bypass high-position collapses, thirteen bridges were built to span potential debris flow gullies, and in-situ treatment measures such as grouted steel pipes and anchor frame beams were implemented for seismically damaged slopes, thereby enhancing the disaster prevention and resistance capacity of the scenic area roads.

These research findings systematically reveal the development patterns of geological disasters in the epicentral region of the Luding earthquake, and the proposed reconstruction strategies have been comprehensively applied in engineering practice, providing important support for disaster identification, assessment, and road reconstruction in strong earthquake zones.

Keywords: Luding earthquake, Hailuogou scenic area road, high-position collapse, seismic damage characteristics, development patterns, reconstruction strategies

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