

Postprint: Safety Research on Red Beds Collapse Hazards at Xining Nanshan Park

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Abstract

Rockfall represents a typical geological hazard widely distributed in red bed regions composed of sandstone, conglomerate, and mudstone. This study investigates the red bed rock wall on the southwestern side of Nanshan Park—the largest modern mountain forest park in Xining City—as the research object. The rock wall, characterized by a steep upper section and gentle lower section, measures approximately 260 m in length and 110 m in height, with lithology comprising interbedded red mudstone and gypsum, constituting a zone highly prone to frequent rockfall disasters. Through field investigations, this research identified the stratigraphic lithology and rock mass structure of the rock wall, elucidated the development characteristics of rockfall phenomena, and determined that the rockfall mechanism in the collapse zone involves the water-induced softening and spalling of gypsum interlayers within mudstone, resulting in cavity and fracture formation beneath mudstone strata, large-scale suspension of mudstone layers, and eventual collapse triggered by rainfall and long-term gravitational effects. Three-dimensional fine-scale measurements were conducted using unmanned aerial vehicle (UAV) technology, with data processed via Context Capture software to obtain rock mass structural data for the Nanshan Park rock wall. Based on these data, a slope structure model of the study area was constructed, and FLAC3D software was employed to perform numerical stability simulation of the rock wall under natural conditions, calculating displacement and deformation values, analyzing rock wall stability and plastic failure zones, and identifying five high-elevation dangerous rock masses. Rocfall software was subsequently utilized to conduct comprehensive simulation analysis of rockfall motion characteristics and disaster-affected ranges from these five locations, revealing that the dangerous rock masses pose severe threats to roads and residential areas below, necessitating immediate preventive measures. According to the numerical simulation results, disaster mechanisms, and practical remediation requirements, this paper recommends implementing “active drainage and passive protection” measures for rockfall disaster prevention in Nanshan Park, with sim-

ulated remediation and effectiveness comparisons conducted for three typical dangerous rock masses. Additionally, targeted recommendations are proposed regarding the emergency response system, operational mechanisms, and workflow for rockfall disasters in Nanshan Park at the current stage. The rock mass structure stability analysis and numerical simulation of rockfall disaster remediation for the special interbedded mudstone-gypsum rock wall collapse zone in Nanshan Park provide valuable references for investigating disaster impacts of rockfalls in high red bed slopes and possess significant engineering applicability.

Full Text

Preamble

Safety Study on Red-Bed Collapse Hazards at Nanshan Park, Xining

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Abstract

Collapse represents a typical geological hazard widely distributed in red-bed regions composed of sandstone, conglomerate, and mudstone. This study focuses on the southwestern red-bed rock wall of Nanshan Park, the largest modern mountain forest park in Xining. The wall features steep upper sections and gentler lower slopes, measuring approximately 260 meters in length and 110 meters in height, with lithology characterized by interbedded red mudstone and gypsum—making it a zone prone to frequent collapse disasters.

Through comprehensive field investigations, we identified the stratigraphic lithology and rock mass structure of the southwestern rock wall, characterized the development features of collapse and rockfall, and determined the hazard formation mechanism. The collapse zone originates from the water-induced softening and spalling of gypsum interlayers within the mudstone, leading to cavity formation and fracturing at the mudstone base, which leaves large areas of mudstone suspended and vulnerable to collapse under rainfall and long-term gravitational stresses. We conducted high-resolution three-dimensional UAV surveys and processed the data using Context Capture software to obtain detailed rock mass structural data for the Nanshan Park wall. Based on these data, we constructed a slope structure model of the study area and performed numerical stability simulations under natural conditions using FLAC3D software. The simulations calculated wall displacement and deformation, analyzed rock wall stability and plastic failure zones, and identified five high-risk unstable rock masses.

Using Rocfall software, we conducted comprehensive simulations of rockfall motion characteristics and disaster ranges for these five unstable masses. The

results reveal that these rock masses pose severe threats to the road and residential areas below, necessitating urgent mitigation measures. Based on the numerical simulation results, disaster mechanisms, and practical remediation requirements, we propose an integrated “active drainage and passive protection” mitigation strategy for the Nanshan Park collapse hazards. We also simulated treatment measures for three typical unstable rock masses and compared their effectiveness. Additionally, we present targeted recommendations for the current emergency response system, operational mechanisms, and workflow procedures for collapse and rockfall disasters at Nanshan Park. This study’s analysis of rock mass stability in the special mudstone-gypsum interbedded collapse zone and numerical simulation of collapse mitigation measures provide valuable insights for investigating disaster impacts in red-bed high-slope environments and offer practical engineering reference value.

Keywords: red beds; collapse and rockfall; rock mass deformation; FLAC3D numerical simulation; Rocfall numerical simulation; emergency response

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

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