Postprint: Quantitative Analysis of Large Rockfall Guiding Steel Wire Rope Ring Nets Based on an Improved Truss Equivalent Method

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Abstract

Efficient design of flexible rockfall guiding nets necessitates a clear understanding of how slope topography influences rockfall energy attenuation and system loads, a task often hindered by the computational cost of traditional models. To this end, this study first developed, calibrated, and validated an improved equivalent truss constitutive model suitable for ring nets based on nine sets of quasi-static and dynamic test data. Systematic numerical analyses were subsequently conducted on the performance of rockfall guiding nets across different slope angles and geometries using the validated equivalent truss method. Experimental data verification demonstrates that the equivalent truss method offers high accuracy advantages, with computational errors consistently maintained within 10%. The key breakthrough lies in the fact that, compared to traditional circular ring beam models, the computational efficiency of the equivalent truss model is improved by approximately 12 times, establishing it as a powerful tool for engineering-scale analysis. Parametric studies reveal that, under protective conditions, the rockfall energy attenuation rate exhibits a linear negative correlation with slope angle. More importantly, slope morphology is confirmed as the dominant factor—although stepped, concave, and Type II composite slopes can enable the high protective performance of rockfall guiding nets, the latter two terrain types generate maximum structural loads within the system. The research findings establish the equivalent truss model as a robust and efficient tool for analyzing rockfall guiding nets, providing a critical theoretical framework and practical methodology for optimizing protection system design by quantitatively correlating net performance, structural demands, and specific terrain conditions.

Full Text

Preamble

Title: Quantitative Analysis of Large-Scale Guiding Flexible Rockfall Barriers Based on an Improved Truss Equivalent Method for Steel Wire-Ring Nets

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Abstract

Efficient design of flexible rockfall guiding nets requires a clear understanding of how slope topography influences rockfall energy attenuation and system loads, a task often hindered by the computational cost of traditional models. To this end, this study first developed, calibrated, and validated an improved truss equivalent constitutive model suitable for ring nets based on nine sets of quasi-static and dynamic test data. Systematic numerical analyses were subsequently conducted on the performance of rockfall guiding nets across various slope angles and configurations using the validated truss equivalent method.

Experimental validation demonstrates that the truss equivalent method achieves high accuracy, with computational errors consistently maintained within 10%. The key breakthrough lies in an approximately twelvefold improvement in computational efficiency compared to traditional ring beam models, establishing it as a powerful tool for engineering-scale analysis. Parametric studies reveal that under protective conditions, the rockfall energy attenuation rate exhibits a linear negative correlation with slope angle. More importantly, slope morphology emerges as the dominant influencing factor—while stepped, concave, and Type II composite slopes enable the high protective performance of rockfall guiding nets, the latter two terrain types generate maximum structural loads within the system.

These research findings establish the equivalent truss model as a robust and efficient tool for analyzing rockfall guiding nets, providing a critical theoretical framework and practical methodology for optimizing protection system design by quantitatively correlating net performance, structural demands, and specific terrain conditions.

Keywords: rockfall protection; truss equivalent model; guiding net; computational efficiency; rockfall energy attenuation rate; system response

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