MOUNTAIN-PLAINS CONSORTIUM

RESEARCH BRIEF | MPC 21-438 (project 482) | June 2021

Coupled Numerical Simulation of Debris Flow-Soil-Structure Interactions for Flexible Barrier Mitigation Systems

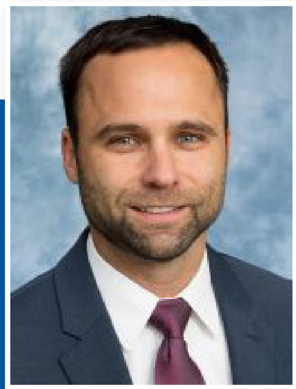
the ISSUE

Debris flows—moving masses of loose solid particles, water, and air—develop primarily on steep slopes. They are an ever-present and growing risk for transportation corridors in the western United States. The ability to understand practical hazard mitigation possibilities prior to the occurrence of a debris flow can provide transportation personnel and consulting engineers vital tools to enhance protection of human life, infrastructure, and the environment. Because of the difficulty of constructing and maintaining other forms of mitigation structures, recent research has focused on the efficacy of flexible steel, ring-net barriers. These barriers are becoming state-of-practice for debris-flow mitigation in mountainous terrain. These structures have been shown effective in geohazard mitigation; however, design of these structures commonly does not incorporate coupled interactions between debris flow mechanics and the stress-strain response of the steel structure. Field and laboratory testing of debris flow barriers are expensive and labor intensive and may not adequately represent loads that could be experienced in actual installations.

the RESEARCH

The objectives of this study were to: 1) create a model using finite element analysis that couples a debris flow and flexible barrier system and 2) evaluate the response of the model to different debris flow and barrier system parameters.

A finite element model (FEM) of a flexible ring-net barrier was developed to simulate the coupled interactions of a debris-flow impacting the barrier and deformation of the barrier. Barrier deformation and stresses induced in the cables predicted with the FEM were comparable to the in-situ field test performed by Ferrero et al. (2015). The FEM yielded a closer prediction of final barrier deformation



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Project Title

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the **RESEARCH** (cont.)

to actual barrier deformation as compared with an analytical model developed by Brighenti et al. (2013). Induced cable tensions predicted by the FEM were comparable to measured tensions and tensions predicted via the analytical model. A parametric study of the flexible ring-net barrier was conducted using the FEM to assess geotechnical and structural engineering parameters. Results from the FEM simulations indicated that the loading induced by the debris flow, more so than the debris flow properties, contributed to the stress and deformation response of the barrier. The parametric study results also emphasized the importance of braking elements' overall barrier performance. The braking elements act as load-reduction mechanisms that allow the barrier to deform upon loading while reducing tension developed in the cables.

the **FINDINGS**

The FEM coupled a debris flow and structural barrier to create a model that captures interaction between a flow and the barrier. Complexity in the numerical simulation of the ring-net structure limited the extent of modeling completed for the debris flow. The debris flow was modeled with individual blocks representing a debris flow instead of simulating the overall flowing mass. This simplification of the debris flows potentially limited the benefit of representing the barrier as a complex system of individual elements. The segmented block flow was representative of an actual debris flow with regard to comparisons of the structural response of the field-scale experiment's structural response. Thus, the segmented debris flow used in the FEM herein can provide insight as to behavior of the barrier during loading; however, additional research is needed to evaluate how different simulations of the debris flow influence response of the flexible ring-net barrier system.

the **IMPACT**

The finite element models developed in this research provide an alternative approach to simulate the complex interactions between a debris flow and flexible steel, ring-net barriers. The work is a step toward developing more complex modeling that will assist in developing barriers that will perform effectively under various scenarios, resulting in improved protection for transportation infrastructure and enhanced safety for travelers.

For more information on this project, download the Main report at https://www.ugpti.org/resources/reports/details.php?id=1040

For more information or additional copies, visit the Web site at www.mountain-plains.org, call (701) 231-7767 or write to Mountain-Plains Consortium, Upper Great Plains Transportation Institute, North Dakota State University, Dept. 2880, PO Box 6050, Fargo, ND 58108-6050.