CFD-DEM modeling of debris flow mitigated by flexible barriers

Researchers: Professor Jidong Zhao *, Xingyue Li #

* Associate Professor at the Hong Kong University of Science and Technology

PhD student at the Hong Kong University of Science and Technology

Visiting student at the University of California, Berkeley in Prof. Kenichi Soga's group

1. Background

Flexible barriers have become increasingly popular in recent years to mitigate the impacts of debris flow. However, no rigorous predictive analytical tools have been established for modeling, analysis and design of flexible debris flow barriers.

2. Methodology

A unified framework of coupled Computational Fluid Dynamics (CFD) and Discrete Element Method (DEM) has been developed to simulate debris flows impacting on flexible barriers. The fluid and solid phases in a debris flow are simulated with CFD and DEM, respectively. The flexible barrier is modeled with DEM by setting particles on the physical nodes of the mesh and connecting these nodal particles by remote interactions (Fig. 1).

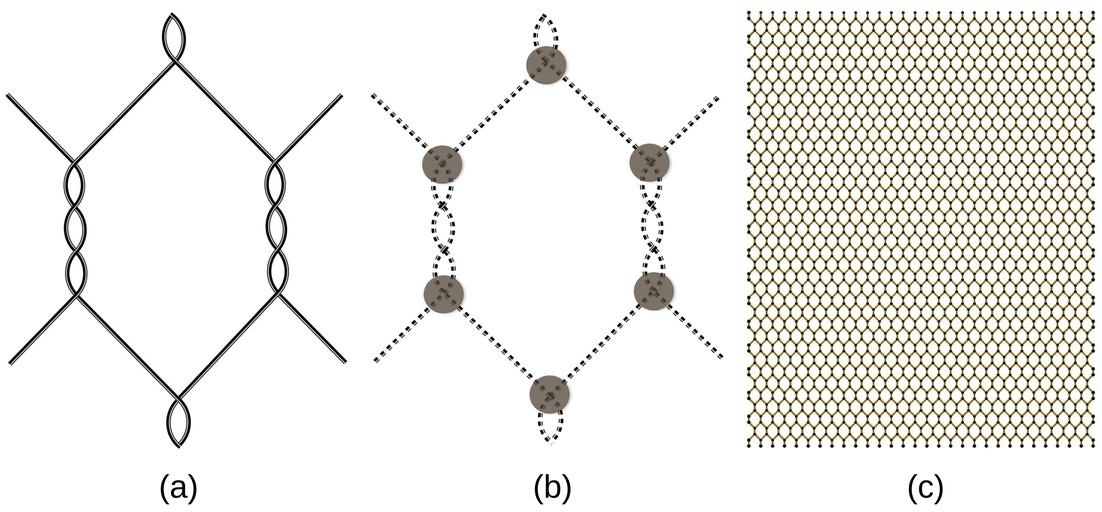

Fig. 1. (a) Illustration of a double-twisted wire net; (b) Discrete particles with remote interactions; (c) Discrete network for a flexible barrier formed by (b)

3. Model setup

A cubic mixture of soil particles and water is initially placed on the top of the slope channel before it is released to flow down and impact on the flexible barrier (Fig. 2). The bottom and lateral edges of the flexible barrier are fixed to mimic anchored boundary conditions.

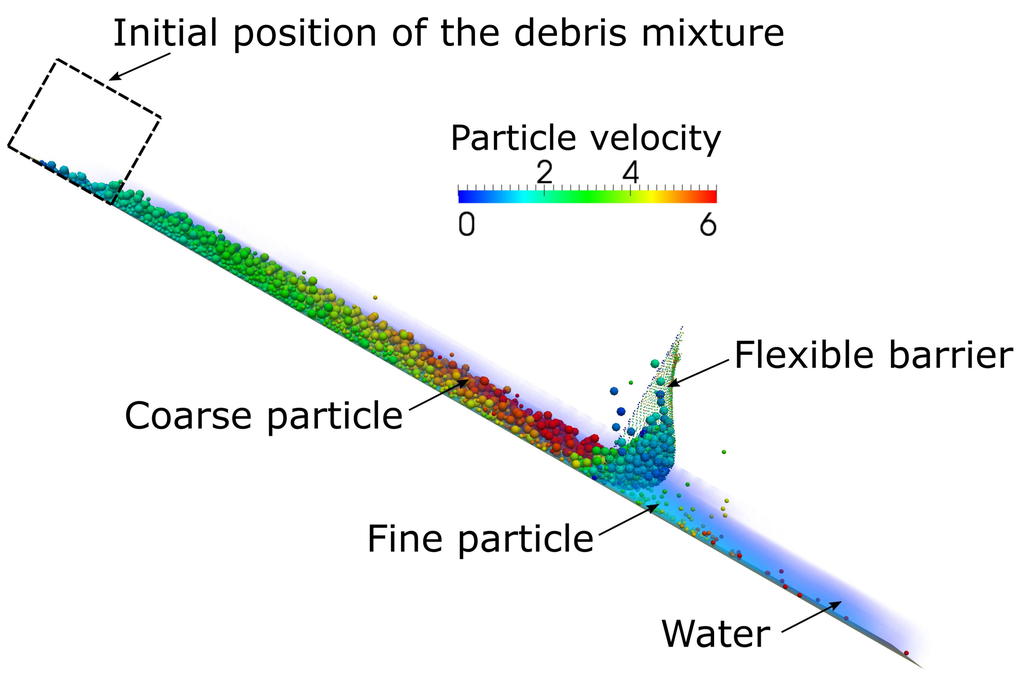

Fig. 2. Model setup for a debris flow impacting on a flexible barrier

4. Uniform barrier

Uniform barriers consisting of single wires have been investigated to examine the possible failure modes a barrier may perform (Fig. 3). Moreover, the effect of barrier stiffness and strength on the maximum sustained force within a barrier is explored.

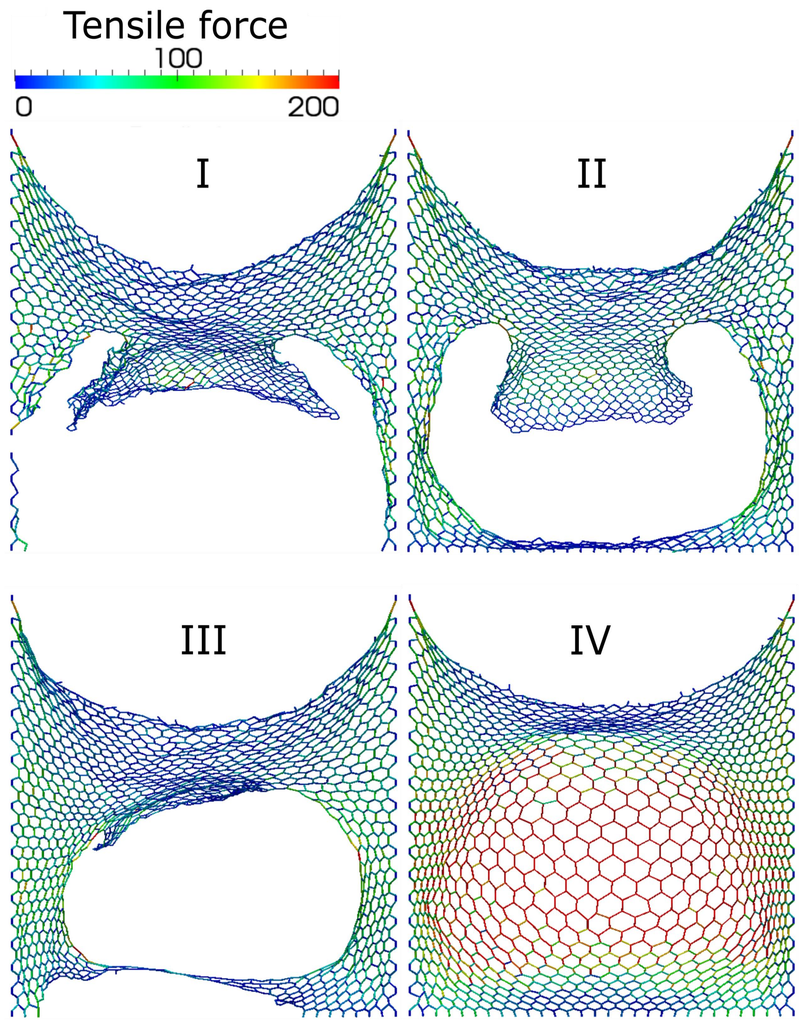

Fig. 3. Flexible barriers with different failure modes (Mode I: Break from bottom edge to lateral edges; Mode II: Break from centre; Mode III: Break from centre and bottom edge simultaneously; Mode IV: Excessive deformation without breakage)

5. Non-uniform barrier

In addition to a uniform barrier composing by single wires, barriers with further consideration of double twists and cables have been studied. Roles played by different components in a barrier are analyzed in terms of barrier deformation (Fig. 4), retained debris mass and sustained force.

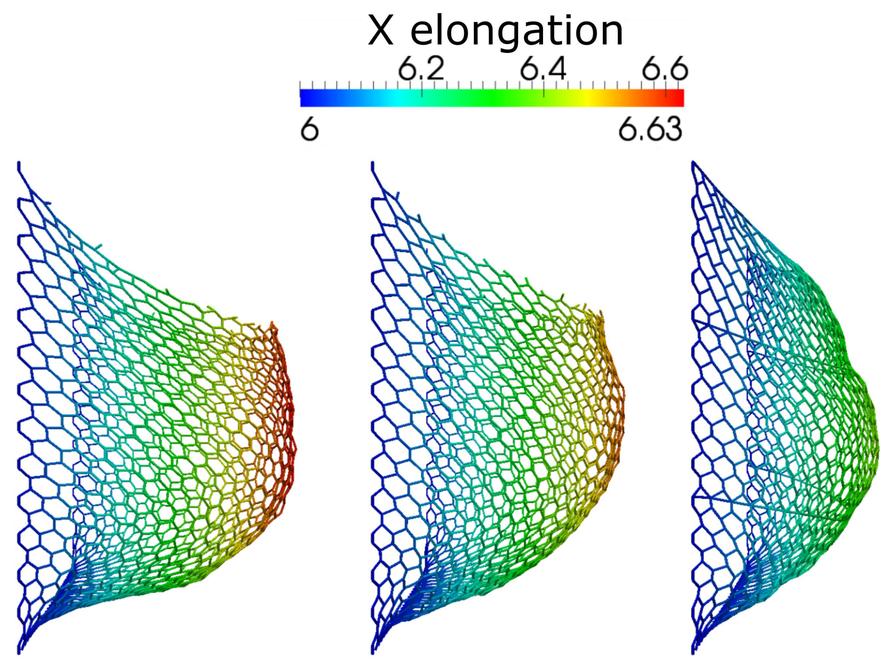

Fig. 4. Side view of deformed barriers (left: uniform net; centre: barrier with double twists; right: barrier with double twists and cables)

Acknowledgement

This research was financially supported by the University Grants Council of Hong Kong by a Theme-based Research Scheme project T22-603/15N.