Mechanism and Prevention of Debris Flow Disaster

Huang, Yu; Sun, Jin; Zhu, Chongqiang

Published in:
Water

DOI:
10.3390/w14071143

Publication date:
2022

Citation for published version (APA):
Huang, Y., Sun, J., & Zhu, C. (2022). Mechanism and Prevention of Debris Flow Disaster. *Water*, *14*(7), Article 1143. https://doi.org/10.3390/w14071143

water

MDPI

Editorial

Mechanism and Prevention of Debris Flow Disaster

Yu Huang [1,*], Jin Sun [2] and Chongqiang Zhu [3]

[1] Department of Geotechnical Engineering, College of Civil Engineering, Tongji University, Shanghai 200092, China
[2] School of Engineering, University of Edinburgh, Edinburgh EH9 3JL, UK; j.sun@ed.ac.uk
[3] School of Engineering and Physical Sciences, Heriot-Watt University, Edinburgh EH14 4AS, UK; chongqiang.zhu@hw.ac.uk
* Correspondence: yhuang@tongji.edu.cn

Debris flow is a disaster that frequently occurs in mountainous regions worldwide due to climate change and human activities and can lead to serious economic losses and casualties. Hence, it is a societal priority to understand debris flow and to develop effective control measures. This Special Issue aimed to contribute to the knowledge and understanding on the mechanisms and evolution law of debris flow and on the performance of protective measures, which are essential to proposing advanced tools and models for disaster mitigation. This Special Issue consists of six articles covering a wide range of topics, including laboratory tests, model tests, and numerical simulations, which are crucial to understand debris flow. Ring shear tests focus on studying the effect of particle crush on the rheological behavior of debris flow [1]. Two model tests are presented to investigate the performance of berm and elastic dam for debris flow [2,3]. Three papers adopted the advanced meshless method to simulate model tests and real debris flow [4–6].

The kernel part of accurately predicting debris flow is an effective constitutive model for geomaterials. However, particle breakage, which is a common phenomenon during debris flow, has been less often considered in the current constitutive model. A very interesting work was conducted by Huang et al. [1] to study the effect of crushing characteristics on the rheological behavior of a granular system using advanced geotechnic ring shear tests. Three kinds of materials, including glass beads, quartz sand, and calcareous sand, were adopted in their experimental research. An innovative analysis method named the classification discussion method was employed to present the degree of fragmentation. This method divides sheared particles into three groups including unbroken particles, partially broken particles, and completely broken particles and then determines their mass ratio. Based on their systematic experiments, they found that the fragmentation degree increased with shear rate; the unbroken material (i.e., glass beads) only presented dilatancy during shear, but the quartz sand and calcareous sand presented dilatancy at the initial shear stage and then showed obvious compression. Moreover, the crushing effect of particles can greatly increase the stress ratio and reduce its fluctuation. More quantitative research will be expected in the future, and it will shed light on the field of granular rheology.

Ryou et al. [2] assessed the performance of berm as a debris flow mitigation measure using well-designed model tests. Berms are stepped structures that separate slopes into many parts to disperse precipitation and to control the velocity of debris flow. Berms offer broad potential applications in urban areas due to their low construction costs and high efficiency. In this paper, the factors including channel slope, volumetric concentration of sediment, and berms were systematically studied. The flow process (including both velocity and Froude number) and deposition features (including runout distance, lateral width, and deposition area) were quantitatively assessed. The experimental results illustrated that berms can effectively reduce the mobility of debris flow. Therefore, berms can be considered as an effective debris flow mitigation measure in the future, but a specific design method in practice needs to be further researched.

check for updates

Citation: Huang, Y.; Sun, J.; Zhu, C. Mechanism and Prevention of Debris Flow Disaster. *Water* **2022**, *14*, 1143. https://doi.org/10.3390/w14071143

Received: 29 March 2022
Accepted: 30 March 2022
Published: 2 April 2022

Huang et al. [3] quantitatively investigated the dynamic behavior of flow–structure interactions to understand the complex impact of debris flow on barrier. The essential part of barrier design is the determination of impact force. However, an impact force is mostly determined using simplified empirical equations without considering flow–structure interactions, which leads to huge damage in the protective structures. Physical model tests are a basic and effective method of investigating debris flow–structure interaction due to its low cost, high-repeatability, and time efficiency. In this paper, a flume test equipment was designed to conduct debris flow dynamic impact experiments with an emphasis on barrier stiffness. The velocity of granular flow, impact force, and the strain of barrier were well recorded using different instruments. The impact-run-up-falling-pile-up process was captured and analyzed based on high-quality video taken by a high-speed camera. An interesting conclusion is found: the impact force strongly affects the barrier stiffness and presents an attenuated trend with the decrease in barrier stiffness. This research provided a fundamental understanding of complex flow–structure interactions and will have a great effect on future research and protective structure design in practice.

Huang et al. [4] is an accompanying paper to Huang et al. [3]. In this paper, the authors studied the effect of barrier stiffness on debris flow dynamic impact using a flow structure coupled with smoothed particle hydrodynamics (SPH). The constitutive behavior of the debris flow and the protective structure is described using a regularized Bingham model and an elastic constitutive model, respectively. The proposed numerical scheme was applied to simulate the model tests reported in [3], and the effectiveness and accuracy is assessed by comparing the experimental and numerical velocity field and the time history of impact force. Good agreement between the experimental and numerical results indicates the high performance of the SPH method used in this work. The SPH method was further applied to study different inclination angles, the initial locations of sand, and the stiffnesses of barrier. This main contribution of this work includes (1) the proposal of a novel numerical method based on a meshless SPH method considering flow–structure interactions; (2) the systematic verification and validation of the proposed numerical method using model tests data; and (3) the application of the numerical method to analyze the interaction between debris flow and a structure to obtain more information that cannot be measured using model tests to facilitate an understanding of the complex interaction process. Further research will be conducted by this group to approach real debris flow by considering water, entrainment, etc.

The flow process and kinetic characteristics of debris flow is essential for disaster mitigation and prevention. However, it is nearly impossible to obtain data from real cases due to the sudden burst and dangers of debris flow. With the rapid development of computer technology, numerical simulations have become an important approach to modelling debris flow. To overcome the limitation of traditional mesh methods, in Dai et al. [5], the SPH is introduced to investigate kinetic features of Yigong debris flow in Tibet, China. A field investigation and a remote sensing analysis were first conducted to obtain geological data and the topography of Yigong debris flow. Both 2D and 3D simulations were conducted in this work. They found that debris flow evolves from the initial acceleration stage to the following dissipating stage due to friction and collision. The kinetic features of Yigong debris flow were revealed by discussing its flow velocity, runout distance, deposition, and energy evolution. A parametric study was also conducted to study the effect of rheological parameters of geomaterials on kinetic properties. Although there are some limitations in the current SPH method, such as substrate entrainment and rock fragmentation, which has not been considered yet, the simulated results can also provide enough information to understand Yigong debris flow and made suggestions for disaster mitigation and prevention of similar disasters.

Debris flow can also occur in submarine environments, which can lead to serious damage to the marine infrastructure and people living in coastal regions. Compared with subaerial debris flow, submarine debris flow can also induce a huge surge wave, which is also a serious disaster. Hence, the propagation of surge waves induced by submarine landslides should also be considered. The contribution from Dai et al. [6] provides a convincing numerical solution to submarine debris flow. In this work, the authors extended their SPH code to submarine debris flow by considering complex interactions between particles and ambient water. A new boundary treatment technique with repulsive particles and a multiphase granular flow algorithm were proposed for submarine debris flow. The updated numerical method was verified and validated using both underwater rigid block slide and underwater sand flow. The numerical results were compared with experimental data (including the displacement of rigid block and wave profiles), and good agreement indicates a high accuracy of the proposed SPH method. Although the current simulation is limited to two-dimensional analyses, the flow process of both debris flow and surge waves are well captured, and can help readers understand the evolution of submarine debris flow and predict its runout.

In conclusion, the articles presented in this Special Issue provide significant contribution to the understanding of the flow processes and mechanisms of debris flow, and the performance of mitigation measures for both researchers and practitioners. Hence, the Guest Editors believe that this Special Issue will greatly arouse readers' interest and stimulate interest in further research based on these articles.

Author Contributions: Y.H., J.S. and C.Z. conceived, designed, and wrote the editorial. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the National Natural Science Foundation of China (grant No. 41831291).

Acknowledgments: The Guest Editors wish to express their gratitude to all authors who submitted their contributions to this Special Issue "Mechanism and Prevention of Debris Flow Disaster" and to all reviewers for taking the time and effort necessary to review the manuscripts.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Huang, Y.; Wang, Y.; Wang, S. Effects of Crushing Characteristics on Rheological Characteristics of Particle Systems. *Water* **2022**, *14*, 532. [CrossRef]
2. Ryou, K.; Chang, H.; Lee, H. Laboratory Analysis of Debris Flow Characteristics and Berm Performance. *Water* **2021**, *13*, 2223. [CrossRef]
3. Huang, Y.; Jin, X.; Ji, J. Effects of Barrier Stiffness on Debris Flow Dynamic Impact—I: Laboratory Flume Test. *Water* **2022**, *14*, 177. [CrossRef]
4. Huang, Y.; Jin, X.; Ji, J. Effects of Barrier Stiffness on Debris Flow Dynamic Impact—II: Numerical Simulation. *Water* **2022**, *14*, 182. [CrossRef]
5. Dai, Z.; Xu, K.; Wang, F.; Yang, H.; Qin, S. Numerical Investigation on the Kinetic Characteristics of the Yigong Debris Flow in Tibet, China. *Water* **2021**, *13*, 1076. [CrossRef]
6. Dai, Z.; Xie, J.; Qin, S.; Chen, S. Numerical Investigation of Surge Waves Generated by Submarine Debris Flows. *Water* **2021**, *13*, 2276. [CrossRef]