

Abstract

The study on impact mechanisms of flow-like landslides against structures is still an open issue in the scientific literature. Many researchers have employed so far either experiments or numerical methods, but the evaluation of the impact forces on mitigation obstacles remains difficult especially if the solid-fluid interaction within the flow is considered. In addition, flow-like landslides are often characterized by large deformations, which depend on slope geometry, soil type and triggering mechanisms.

Throughout the past decades many numerical methods aiming to simulate large deformations have been introduced, as for example Discrete Element Method (DEM), Smooth Particle Hydrodynamics (SPH), Updated Lagrangian Finite Element Method (UL-FEM) and Material Point Method (MPM). All of them are based on different theories, capabilities, and accuracy, but the complexity is their common feature. In fact, the response of landslide body under large deformations is still unclear, especially for Landslide-Structure-Interaction (*LSI*) problems, due to: i) the hydro-mechanical features of the impacting flow, ii) the geometry and stress-strain response of the structure, and iii) initial and boundary conditions for the specific *LSI* problem. Numerical methods greatly contribute to a safer and more cost-effective design of landslide mitigation works. However, most of these approaches are very recent, and still need comprehensive validation.

The advanced numerical technique of the Material Point Method (MPM) is used in this thesis to provide a novel contribution in investigating the dynamics and the impact mechanisms of flow-like landslides against protection structures, thanks to its capability of considering both the coupled hydro-mechanical behaviour of the propagating mass and large deformations of the approaching flow. The MPM numerical method is validated against observations coming from famous landslide benchmarks (like the Fei Tsui Road landslide or the Wenjia gully debris flow) or from well documented laboratory experiments investigating the impacts of granular flows against rigid obstacles. Then, the model is used to explore the response of different flows impacting rigid barriers, focusing the attention on the potential efficiency of different types of barriers in intercepting the propagation of the flow under several impact conditions. The study principally highlighted that the soil-fluid interaction within the flow and the barrier geometry influence the type of impact mechanism, the kinematics of the flow, and the space-time trend of the impact forces against the structure.

The satisfactory validation of MPM also allows to derive simplified analytical and empirical models for estimating the temporal trend of the impact force on a rigid structure and the kinetic energy reduction of the flow during impact. However, the assumption of rigid body used for the design of these barriers must be analysed. For this reason, additional stress-strain analyses on two different mitigation options (such as Reinforced-Concrete walls and Deformable Geosynthetics-Reinforced Barriers) were conducted for examining the extent of internal deformations and the possible ultimate limit states of the structure under impact.

As a conclusion, the research shows how multi-phase, hydro-mechanical coupled and large deformations numerical methods are of primary importance for modelling flow-like landslides dynamics and for studying the interaction mechanisms between the landslide and the structure.