# A Lagrangian Finite Element approach to the numerical simulation of 3D large-scale landslides

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## ABSTRACT

Landslides are exceptional natural hazards that can generate extensive damage to structures and infrastructures causing a large number of casualties. Instability of a slope can be triggered by natural events (erosion, earthquakes, intense rainfalls…) or by human activities (deforestation, construction…). Once initiated, a landslide can run along a slope with different velocities and cover long distances, depending also on the slope morphology. A particularly critical condition occurs when the landslide impinges in water reservoirs generating high waves [1-3]. Consequently, the interest for numerical tools capable to simulate landslides with potentially long runout distance, including their interaction with water basins, is continuously growing.

This work proposes a numerical tool to simulate the macroscopic behaviour of a propagating landslide. The Particle Finite Element Method [2-4] is here reconsidered and adapted to the specific case of landslide runout. The Lagrangian Navier-Stokes equations of incompressible fluids are used to describe the macroscopic landslide behaviour. A rigid-visco-plastic law with a pressure dependent threshold, typical of a non-Newtonian, Bingham-like fluid, is used to characterize the constitutive behaviour of the flowing material.

The Lagrangian nature of the approach allows for a natural treatment of free surfaces undergoing large displacements and of fast evolving interfaces, making the method particularly suitable for the simulation of landslide phenomena. Due to the excessive distortion of the mesh, typical of Lagrangian approaches for fluids, a continuous remeshing, based on a fast 3D Delaunay triangulation, is implemented. A 3D version of the so called “alpha-shape” technique [4] is used to define the position and the evolution of the free-surfaces. Special attention is devoted to the definition of ad-hoc pressure-dependent slip boundary conditions at the interface between the flowing mass and the basal surface to better represent the real landslide-slope interaction.

The proposed approach has been validated against numerical benchmarks and small scale experimental tests, showing a good agreement with the physical measurements. Real case scenarios have also been considered. 3D geometries of critical sites, where landslides have occurred, have been reconstructed allowing for the simulation of large scale real landslide runouts. Results are compared with post-event images and measurements, showing the accuracy and the capability of the method.

## REFERENCES

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