EGU21-15352, updated on 23 Oct 2021
https://doi.org/10.5194/egusphere-egu21-15352
EGU General Assembly 2021

Investigation of The Observed Time-lag Between the Simulated Peak Pore Pressures and Slope Failures in Rainfall Induced Landslides: A Numerical Approach

Krishnendu Paul[1], Pathikrit Bhattacharya[2], and Santanu Misra[1]
[1]Indian Institute of Technology Kanpur, Earth Sciences, India (krishnendupaul1991@gmail.com)
[2]National Institute of Science Education and Research, School of Earth and Planetary Sciences, India (pathikritb@niser.ac.in)

Rainfall-induced landslides pose a substantial risk to people and infrastructure worldwide, but their mechanical behavior is not well understood. As a result, hazard predictions for these landslides, especially for rainfall and slope-failure correlations, remain an active area of research. Many operational rainfall-induced landslide hazard maps still assume a classical Coulomb type failure criterion where slope-failure must occur either before or at peak subsurface pore pressure reached during a precipitation event. Using satellite-derived surface precipitation data and soil infiltration simulations over a 15 day period preceding 121 rainfall-induced landslides across India, we find that these events occurred systematically 2-12 days after the simulated peak pore pressures on the inferred failure slope nucleating between 0.5 and 5 m depth. These observations cannot be explained with the Coulomb failure criterion, since failure on these slopes is significantly delayed behind the occurrence of the inferred strength minimum. Instead, in this study, we investigate whether a slope failure model with time- and slip-variable shear strength, governed by the rate-state friction (RSF) equations widely used in earthquake mechanics, can explain the observed ranges of time-delays between slope failure and inferred peak pore pressure.

To concentrate on the role of the constitutive behavior of the failure surface, we examine spring-slider dynamics under a classical RSF framework driven by variable on-slope and far-field pore pressure and flux time histories. We derive analytical expressions for the time-to-failure of such a spring-slider under simple pore pressure perturbation histories and find that the delay-times can vary significantly depending on the laboratory derivable RSF parameters, soil bulk properties, and particulars of the pressure history. We further examine the roles of dilatancy strengthening and pore compaction in determining the time-lag between peak pore pressure and slope failure. We find that dilatancy can have either a stabilizing or a destabilizing effect on slope failure depending on the hydrological and mechanical properties of the failure plane and the soil column. Finally, we show with numerical simulations that periodic pore pressure or flux oscillations can also drive asynchronous repeated slope failures in both the presence and absence of the coupling of pore pressure and shear deformation. Our results show that the observed rainfall-landslide correlations for these 121 landslides can be explained with inherently time- and slip-dependent shear strength prescriptions like the RSF equations. This, in turn, implies that realistic landslide hazard monitoring might require the examination of soil shear strength under the experimental

protocols widely used in rock friction experiments to determine whether the constant friction assumption inherent in the Coulomb criterion needs to be revised in favor of RSF or similar constitutive equations for shallow landslides.