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Postprint: Research on Landslide Deformation Mechanisms and Characteristics

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Abstract

The complex deformation behavior of landslides can be described by the three-stage deformation curves of geomaterials, providing an effective phenomenological tool for early warning and prediction. However, the physical mechanism underlying the three-stage deformation of landslides remains unclear to date, hindering the development of precise landslide prediction. This paper, based on D' Alembert' s principle, restores the dynamic nature of the deformation process prior to landslide instability and establishes a dynamic model for landslide deformation by considering the strain-softening properties of geomaterials. This model can express the three-stage deformation characteristics of landslides under constant gravitational loading. Model analysis reveals the following findings: (1) The initial stage of landslide deformation can be divided into two sub-stages: initiation and deceleration. The constant-velocity deformation recognized in traditional understanding is not truly constant in velocity, but rather an apparent result of slowly varying velocity; (2) The intrinsic condition for landslide instability under gravitational action is theoretically derived, namely that the driving stress generated by gravity must exceed the limiting stress of the geomaterial itself but remain below the peak strength, and this limiting stress can be directly calculated from shear strength parameters; (3) The theoretical model clarifies that landslide mass and the brittle nature of geomaterials are intrinsic factors influencing landslide deformation behavior; (4) Inertial forces drive the landslide system to generate a positive feedback mechanism that controls the nonlinear accelerated deformation of the landslide; (5) The strain-softening properties of the material and inertial forces jointly control the three-stage deformation behavior of landslides. The dynamic model for landslide deformation provides a new theoretical methodological framework for calculating landslide deformation, revealing landslide failure mechanisms, and advancing time-prediction efforts.

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Full Text

Preamble

Research on the Deformation Mechanism and Characteristics of Landslides

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Abstract

The complex deformation behavior of landslides can be described by the three-stage deformation curve of geotechnical materials, providing an effective phenomenological tool for early warning and prediction. However, the physical mechanism underlying this three-stage deformation remains unclear, which has hindered the development of accurate landslide forecasting. This paper reconstructs the dynamic essence of the pre-failure deformation process based on D' Alembert's principle and establishes a landslide deformation dynamic model that incorporates the strain-softening properties of rock and soil masses. The model successfully reproduces the three-stage deformation characteristics of landslides under constant gravitational loading.

Through model analysis, several key findings emerge. First, the initial deformation stage can be subdivided into initiation and deceleration sub-phases, revealing that the traditionally recognized "constant velocity" deformation is not truly constant but rather an apparent result of slowly varying velocity. Second, we derive the intrinsic condition for landslide instability under gravity: the driving stress generated by gravity must exceed the material's limit stress yet remain below its peak strength, with this limit stress being directly calculable from shear strength parameters. Third, the theoretical model demonstrates that landslide mass and the brittle nature of geotechnical materials are intrinsic factors governing deformation behavior. Fourth, inertial forces drive a positive feedback mechanism within the landslide system, controlling the nonlinear accelerated deformation. Finally, both the strain-softening properties of materials and inertial forces jointly control the three-stage deformation behavior. This dynamic model for landslide deformation provides a novel theoretical framework for calculating deformation processes, revealing failure mechanisms, and advancing time-dependent forecasting efforts.

Keywords: landslide; three-stage deformation; dynamic model; inertial force; strain-softening

Note: Figure translations are in progress. See original paper for figures.

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