Geophysical Research Abstracts,
Vol. 10, EGU2008-A-07186, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-07186
EGU General Assembly 2008

Slope instability of a granular layer under seepage flow: start and stop of an avalanche

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Gravitational stability of a soil is a major concern either for civil engineering structures or for natural hazards since slope failures can trigger large surface avalanches, massive landslides or potentially devastating debris flows. For fully saturated soils, ground water seepage affects soil stability and, according to streamlines orientation versus gravity, can possibly lead to fluidization or to slope failure. Downstream face sliding on a earth dam, submarine landslide or quicksand are some related examples of gravitational instabilities induced by seepage.

This contribution deals with the situation of an immersed granular medium submitted to a seepage flow with a constant hydraulic gradient, either in upward or downward direction in respect to its free surface normal. Our goal is to understand how the seepage force exerted on the grains by the flow will enhance or reduce the overall stability of the medium and its subsequent destabilization. In the specific case of granular media, the stability threshold is the so called avalanche angle and we report here experimental results on the avalanche angle of a granular layer as a function of the applied hydraulic gradient. A unique avalanche threshold is derived by two alternative theoretical developments, namely a continuum and a discrete approach, and is successfully confronted to the collected data in a large experimental range. A qualitative analysis of the instability triggering reveals different dynamical behaviours depending on the direction of the seepage flow, namely stabilizing versus destabilizing regime. After the avalanche has stopped, the repose surface of the sample is not linear as in the hydrostatic situation because the hydraulic gradient is no more constant in the medium. A simple model is proposed that can satisfactory predict the post-avalanche height profile as

well as its subsequent evolution for higher inclinations.