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Defining the volume and geometry of the landslide failure surfaces: a review with emphasis on the Sloping Local Base Level (SLBL)

Michel Jaboyedoff, Sergio Daicz, Marc-Henri Derron, Ivanna Penna, and Benjamin Rudaz
University of Lausanne, CRET-FGSE, CH-1015 Lausanne, Switzerland (michel.jaboyedoff@unil.ch, +41 21 692 3535)

Even though computers capability permits now to go to 3D representation, few recent methods are available for the construction of the landslides failure surfaces or profiles without the need of geophysical or boreholes data. In this study we will review the morphometric approaches, displacements observations, and interpolation techniques that are generally used for the determination of landslide volumes and failure surfaces. In a last step we describe a new methodology coming from signal processing methods.

The first group of methods provides cross-sections displaying profiles of potential failure surfaces. These methods are based on simple rules, empiric or not, using morphometric features. The simplest one is to assume a profile tangent at the top scarp or laterally of the failure surface and at its intersection with the topography, and then to extrapolate by hand from those points the failure surface or to use splines. In the case of rotational landslides, when the block rotated and the scarp displacement is measurable, it is possible to deduce the radius of the circle defining the failure surface. A second group of methods uses observed displacements and geometry changes at the surface: (1) The thickness of a translational landslide can be obtained from surface displacement and material deficit at the crown, similarly to balanced cross-sections used in structural geology; (2) Circular failure surface can be obtained by using the displacement vector of surface features and a simple geometrical construction assuming that the displacements are perpendicular to the radius of the circle of failure. In the case of rock slope instabilities, based on spacing and orientation distributions of two discontinuity sets, it is possible to estimate the probability that a stepped surface daylights the bottom of a slope.

Volume of landslide deposits can be roughly estimated by using half-ellipsoid, or a simple landslide surface multiplied by an average thickness. Various empirical relationships between surface and volume have been proposed for different contexts. In the case of debris-flows, the classical way is to perform surveys multiplying the surface of the section of available sediments by the length of reaches. It is also possible to use polynomial functions to estimate the transversal profile section.

Estimation of 3D failure surfaces and volumes is performed nowadays using DEM. Based on the morphometric features providing the limits of the instable volume of rocks, the failure surface can be estimated by interpolation using various techniques such as 3D splines, surface fitting, etc. For rockslides, the observations of major discontinuities defining the instability, using orientation data and extrapolations in the ground, permits to define the geometry of an unstable rock mass.

A technique that can be used in any case is the Sloping Local Base Level (SLBL) that comes from the signal processing methods. It joins by an iterative algorithm the limits of the landslide by a surface of a given curvature. This surface can also be constrained by a slope angle limit of the failure surface. The SLBL process “excavates” iteratively the topography. It can be either applied directly to the grid nodes or using local surface fitting. Limiting the iteration permits an application to estimate material available in debris-flows prone torrent reaches. Finally, if an inventory of landslides and a DEM are available, this methodology have as advantage to automatically and in a short period of time, determine volume statistics and estimations of failure surfaces at regional scale.

All those methods are important, especially for modelling, because they can provide information when investigations are lacking. The estimated failure surfaces can then be used to check the coherence of the surface movements.