Rock avalanche mobility – what is its optimal characteristics?

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Abstract: Rock avalanches (RA) – one of the most hazardous types of slope processes in mountainous regions, are characterized by an abnormally high mobility. Physically it can be described in terms of velocity (v) that, according to very few direct measurements and to the numerous data on the RA debris runup (h) on the opposite slope of a valley ($v=(2gh)^{0.5}$) could reach 300-400 km/hour. Traditionally, since pioneering works of Albert Heim, RA mobility is characterized by angle of reach – ration of height drop and runout (H/L), where H is the elevation difference between headscarp crown and the deposits tip, and L – the horizontal projection of the distance between these two points along the RA travel pass. It was found that H/L value decreases drastically with increasing volume of failure (V).

However, as it was demonstrated by F. Legros (2002), statistically the correlation coefficient of the relationship between V and just L is higher than that of the relationship between V and H/L. Same conclusions were made based on the Central Asian RA database (Strom, Abdrakhmatov, 2018; Strom et al., 2019). Thus, runout prediction of the slope failure of the given volume should be more accurate than that of the H/L.

Besides, the geometric characteristics of the mobility can be not only the runout, but also the affected area. An important parameter required for risk assessment is the exposure of elements at risk, which depends, foremost, on the area, either total (A_{total} = source area +travel area + depositional area), or just on the area, covered by RA deposits (A_{dep}). And R^2 coefficients of the ($A_{total,\ dep}$ – V) relationships appear to be higher than those of the (L – V) relationships. It should be pointed out that producing such statistical correlations we must consider the confinement conditions of RA motion. Indeed, it is meaningless to compare geometric parameters (L, A) of the unconfined RA that move over the free, unbounded surface of wide neotectonic depression where debris can spread both forward and sidewise, with such parameters of the RA moving just down-valley and confined by valley slopes, or with frontally confined RA that either collides with steep opposite slope or climbs on it, overcoming the gravity force. ($A_{total,\ dep}$ – V) relationships derived for these three main types of confinement conditions have much higher R^2 coefficients than those for (L – V).

The highest R^2 coefficients have the relationships between the geometrical mobility parameters (L, A_{total}, A_{dep}) and the V×H product that is somehow proportional to the potential energy released during rock avalanche emplacement (Strom, Abdrakhmatov, 2018; Strom et al., 2019; Strom, 2024). It is evident that the mobility is governed by the kinetic energy, which main, if not the only source is the potential energy and it is really surprising that such relationships have been quite rarely analyzed before.

One more problem that deserves to be discussed, is the selection of parameters that should be used to derive relationships suitable for prediction of the runout or the affected area of the events that are just anticipated. Such assumption means that we can roughly assess possible failure volume V. But values of the vertical and horizontal distanced between headscarp crown and the deposits tip (H, L) are unknown until the event occurs. Thus, for the predictive purpose it is logical to use the height of the unstable slope (H_s) instead of H and to compare L, A_{total}, and A_{dep} with the V×H_s product (Strom, 2024). The variability range of the parameters used to derive the empirical relationships should be considered as well.