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LiDAR-based investigation of debris flow superelevation and velocity

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Debris flows are a highly hazardous landslide type, and their impact forces, peak discharges and runout distances are dependent on the flow velocity. Knowledge of flow velocities is therefore often required for hazard planning and mitigation, as well as for validating numerical models. One commonly used method for post-hoc estimation of debris flow velocities uses the mudlines left behind by a passing flow as it travels through a bend. The surface inclination derived from these mudlines can be used to estimate velocity based on the forced vortex equation, originally developed for clear water flows and later adapted to debris flows using a correction factor k to back-calculate the flow velocity[1,2]:

$$v_{df} = \left(\frac{R_c g^*}{Bk}\Delta h\right)^{0.5} \qquad (1)$$

where R_c is the radius of curvature of the bend, $g*$ is the bed-normal component of acceleration due to gravity, B is the flow width, and Δh is the difference in elevation of the flow surface between the inner and outer bend.

This approach involves some uncertainties, however, such as how best to define the radius of curvature, the influence of roll waves and splashing on the post-event mudlines used to measure the surface inclination, as well as the meaning and appropriate value of the correction factor k. In this study, we first derive a database of superelevation velocity estimates based on pre- and post event UAV data for seven events from the years 2019 to 2021 in the monitored Illgraben torrent in Switzerland. Analysis of this database firstly indicates that the placement of cross-sections for surface inclination measurements is more important than how the radius of curvature is defined due to the large influence of local topography on mudlines. Secondly, the data indicates that the correction factor k increases nonlinearly with decreasing Froude numbers, as has been previously suggested[2,3]. The correction factors were back-calculated using eq. 1 and reference velocities from geophone detections of the front arrival, and seemed to range between approximately 1 and 7.

We next present a first comparison of these data to surface inclination and radius of curvature values derived from high-resolution 3D LiDAR scanners for one event in the summer of 2022. We use this unique dataset to directly derive the radius of curvature (based on surface velocity vectors) and surface inclination of the flow, as well as the appropriate correction factor. We compare these values to those derived by the above-mentioned commonly used method based on bend topography and post-event mudlines to assess the efficacy of these methods. This preliminary study thus provides a validation of the superelevation approach and will provide a basis for more in-depth research on this topic.

[1] Hungr, O., Morgan, G.C. and Kellerhals, R., 1984. Quantitative analysis of debris torrent hazards for design of remedial measures. *Canadian Geotechnical Journal*, *21*(4), pp.663-677.

[2] Scheidl, C., McArdell, B., Nagl, G. and Rickenmann, D., 2019. Debris flow behavior in super-and subcritical conditions. *Association of Environmental and Engineering Geologists; special publication 28*.

[3] Scheidl, C., McArdell, B.W. and Rickenmann, D., 2015. Debris-flow velocities and superelevation in a curved laboratory channel. *Canadian Geotechnical Journal*, *52*(3), pp.305-317.